THE PRINCIPLES OF FEEDING FARM ANIMALS

BY

SLEETER BULL, B.S., B.S.Ag., M.S.

ASSOCIATE IN ANIMAL NUTRITION, COLLEGE OF AGRICULTURE
AND AGRICULTURAL EXPERIMENT STATION OF
THE UNIVERSITY OF ILLINOIS

New York
THE MACMILLAN COMPANY
1916

All rights reserved

Copyright, 1916,
By THE MACMILLAN COMPANY.

Set up and electrotyped. Published September, 1916.

Norwood Press
J. S. Cushing Co. — Berwick & Smith Co.
Norwood, Mass., U.S.A.

THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO · DALLAS
ATLANTA · SAN FRANCISCO

MACMILLAN & CO., LIMITED
LONDON · BOMBAY · CALCUTTA
MELBOURNE

THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

PREFACE

This volume is an outgrowth from a class manual written several years ago by the author for the use of elementary students at the University of Illinois in a general course in stock-feeding. Inasmuch as there has been some little demand for the class manual from outside sources, the author has rewritten the original manuscript and added a number of valuable illustrations and tables.

An effort has been made to present the scientific facts underlying the art of feeding animals in such a manner that the book will not only be suitable for use as a text for college courses in general feeding, but will also be valuable to the farmer who has not had a technical education in agriculture. Thus it has been deemed wise to omit many minor details and a large part of the mass of experimental data from which the general conclusions are deduced.

In the first six chapters the author has discussed the scientific aspects of the subject and has attempted to present them in a simple, concise manner so that they may be easily understood, not only by the student but also by the feeder who desires to familiarize himself with the scientific principles underlying the art of stock-feeding. A large number of drawings and photographs illustrating points in the discussion should be of great value in this connection.

On account of the "back to the land" movement which is sending men from the cities to the agricultural colleges and to the farm, a mere discussion of balanced rations and feeding standards has not seemed sufficient. Consequently the author has presented rather definite rules regarding the feeding of the different classes of live stock which, taken in connection with the feeding standards and the discussion of the nutritive value of the different feeds, should enable the inexperienced feeder to formulate at least fairly satisfactory rations. This point has also been kept in mind in treating of the feeding values of the different feeds, and an attempt has been made to make specific rather than general statements regarding the amounts, proportions, and combinations of feeds in the rations of different classes of farm animals. It has also seemed of value to insert illustrations of the principal crops used for feeding.

It has seemed desirable, partly in order to avoid duplication, to discuss the use of each of the principal feeds for the different species and classes of live stock rather than to devote separate chapters to the feeding of the different classes of farm animals. For example, under the discussion of corn, its use is given in the rations of growing cattle, colts, pigs, and lambs; fattening cattle, hogs, and sheep; breeding cattle, horses, hogs, and sheep; dairy cows; and work horses.

In addition to the discussion of the nutritive value of feeds and rations, the author has given particular attention to their fertilizing values, a phase which is often neglected both by the student and the stockman.

The author is deeply indebted to Professor H. S. Grindley, Dr. H. H. Mitchell, Professor W. C. Coffey, Professor H. P. Rusk, Professor J. L. Edmonds, Mr. W. J. Carmichael, Mr. C. I. Newlin, and Mr. R. S. Hulce of the University of Illinois,

to Dr. W. E. Joseph of the Montana Agricultural College, and to Professor J. M. Evvard of the Iowa State College for many valuable suggestions and criticisms, and he extends to them his sincere thanks. He also thanks the Illinois Experiment Station for the use of unpublished data; and The Macmillan Company, The Chicago Medical Book Company, The W. B. Saunders Publishing Company, Bailliere, Tindall and Cox, Professor H. W. Mumford, United States Department of Agriculture, United States Bureau of the Census, Ohio Experiment Station, Wisconsin Experiment Station, Kentucky Experiment Station, Connecticut Experiment Station, Pennsylvania Experiment Station, Vermont Experiment Station, Missouri Experiment Station, Iowa Experiment Station, Cornell Experiment Station, and Illinois Experiment Station for the use of illustrations.

SLEETER BULL.

URBANA, ILLINOIS
July, 1916.

CONTENTS

CHAPTER		PAGE
	INTRODUCTION	xvii
I.	THE CHEMICAL COMPOSITION OF FEEDINGSTUFFS	1
II.	THE CHEMICAL COMPOSITION OF FARM ANIMALS	25
III.	THE DIGESTION OF THE NUTRIENTS	34
IV.	THE DIGESTIBILITY OF FEEDINGSTUFFS	56
V.	FUNCTIONS OF THE FEED NUTRIENTS IN THE ANIMAL BODY	76
VI.	ENERGY IN FEEDINGSTUFFS AND ITS USES IN THE ANIMAL BODY	92
VII.	THE COMPOUNDING OF RATIONS	107
VIII.	THE FEED REQUIREMENTS OF FARM ANIMALS	119
IX.	GRAINS AND SEEDS	157
X.	THE CEREAL BY-PRODUCTS	188
XI.	THE OIL BY-PRODUCTS	206
XII.	THE PACKINGHOUSE BY-PRODUCTS	216
XIII.	MISCELLANEOUS CONCENTRATES	221
XIV.	THE HAYS	232
XV.	FODDERS AND STOVERS	256
XVI.	THE STRAWS	263
XVII.	PASTURE OR FORAGE, AND SOILING CROPS	266
XVIII.	SILAGE	287
XIX.	MISCELLANEOUS ROUGHAGES	296
XX.	THE EFFICIENCY OF RATIONS	305
XXI.	THE FERTILIZING VALUES OF FEEDINGSTUFFS	320
XXII.	THE VALUATION OF FEEDINGSTUFFS	330
	APPENDIX	335

ILLUSTRATIONS

FIGURE		PAGE
1.	Composition of steers from 100 to 1200 pounds. (T. L. Haecker, Minnesota Experiment Station)	29
2.	Porterhouse steak from a prime steer. Note the "marbling." (Illinois Experiment Station)	32
3.	Digestive tract of man — schematic. (Paton, Veterinary Physiology, Chicago Medical Book Company)	35
4.	Stomach of the horse: (Sisson, Veterinary Anatomy, W. B. Saunders Publishing Company)	36
5.	Cæcum of the horse. (Smith, Manual of Veterinary Physiology, Bailliere, Tindall and Cox)	37
6.	Head of cow, showing some of the salivary glands. (Sisson, Veterinary Anatomy, W. B. Saunders Publishing Company)	38
7.	*Digestive tract of the horse. (United States Department of Agriculture)*	39
8.	Stomach of a sheep. (United States Department of Agriculture)	44
9.	*Cross-section of mucous membrane of the small intestine.* (Jordan, Principles of Human Nutrition, The Macmillan Company)	48
10.	Longitudinal section of a villus. (Jordan, Principles of Human Nutrition, The Macmillan Company)	49
11.	Loop of small intestine of the horse during active absorption. (Smith, Manual of Veterinary Physiology, Bailliere, Tindall and Cox)	50
12.	Digestion harness on a pig (Illinois Experiment Station)	57
13.	These pigs were fed a ration deficient in phosphorus. (Wisconsin Experiment Station)	78
14.	These pigs were fed the same ration as those in Figure 13, with the addition of phosphorus in the form of calcium phosphate. (Wisconsin Experiment Station)	79
15.	Abnormal bones from hogs whose rations were low in calcium (corn alone, and corn and soybeans). (Ohio Experiment Station)	80

FIGURE PAGE

16. The ration of these pigs was deficient in the amount and quality of protein. (Illinois Experiment Station) 83
17. The ration of these pigs contained sufficient protein of the proper quality. (*Illinois Experiment Station*) 84
18. The effect of the amount and kind of protein upon the bones of growing pigs. (Illinois Experiment Station) . . . 85
19. Pigs at the beginning of a 196-day feeding period upon corn alone. (Kentucky Experiment Station) 86
20. The same pigs as shown in Figure 19 after 196 days of feeding corn alone. (Kentucky Experiment Station) 87
21. Section of bomb calorimeter. (Connecticut (Storrs) Experiment Station) 94
22. Respiration calorimeter at the Institute for Animal Nutrition, State College, Pa. (H. P. Armsby, Pennsylvania Experiment Station) 96
23. Cross-sections of haystacks of different shapes showing the corresponding values for "F." (United States Department of Agriculture) 117
24. A self-feeder for cattle. (Mumford, Beef Production) . . . 153
25. A self-feeder for hogs. (Illinois Experiment Station) . . . 154
26. Corn production in the United States. (United States Census) 158
27. An ear of dent corn. (Livingston, Field Crop Production, The Macmillan Company) 160
28. Cross-section of a kernel of dent corn. (Livingston, Field Crop Production, The Macmillan Company) 160
29. An ear of flint corn. (Livingston, Field Crop Production, The Macmillan Company) 161
30. Cross-section of a kernel of flint corn. (Livingston, Field Crop Production, The Macmillan Company) 161
31. Distribution of oat production in the United States. (United States Census, 1910) 170
32. Ergot in a head of rye. (Duggar, Southern Field Crops, The Macmillan Company) 175
33. A head of barley. (Livingston, Field Crop Production, The Macmillan Company) 176
34. Distribution of barley production in the United States. (United States Census, 1910) 177
35. A head of emmer. (Livingston, Field Crop Production, The Macmillan Company) 178

FIGURE PAGE

36. A head of spelt. (Livingston, Field Crop Production, The Macmillan Company) 179
37. Heads of the principal types of sorghums. (Montgomery, The Corn Crops, The Macmillan Company) 180
38. Seeds of the principal types of grain sorghums. (Montgomery, The Corn Crops, The Macmillan Company) 181
39. A panicle of rice. (Livingston, Field Crop Production, The Macmillan Company) 182
40. Ten varieties of cowpeas. (Piper, Forage Plants, The Macmillan Company) 183
41. Ten varieties of soybeans. (Piper, Forage Plants, The Macmillan Company) 184
42. Pods of cowpeas and soybeans. (Livingston, Field Crop Production, The Macmillan Company) 184
43. *Root of peanut. (Livingston, Field Crop Production, The Macmillan Company)* 185
44. A cotton plant. (Livingston, Field Crop Production, The Macmillan Company) 186
45. Structure of the corn kernel. (Illinois Experiment Station) . 189
46. Section of wheat kernel. (Jordan, The Feeding of Animals, The Macmillan Company) 194
47. *Weeds growing from seed found in a commercial feed containing screenings.* (Vermont Experiment Station) . . 200
48. Buckwheat in bloom. (Livingston, Field Crop Production, The Macmillan Company) 204
49. Distribution of hay and forage in the United States. (United States Census, 1910) 233
50. Red clover. (Livingston, Field Crop Production, The Macmillan Company) 234
51. Production of clover in the United States. (Hitchcock, A Textbook of Grasses, The Macmillan Company) 235
52. An alfalfa plant. (Livingston, Field Crop Production, The Macmillan Company) 237
53. Distribution of alfalfa in the United States. (United States Census, 1910) 238
54. Arrangements of leaflets of alfalfa and clover. (Livingston, Field Crop Production, The Macmillan Company) . . . 239
55. *Alsike clover. (Livingston, Field Crop Production, The Macmillan Company)* 241

FIGURE PAGE

56. Sweet clover. (Piper, Forage Plants, The Macmillan Company) 242
57. A crimson clover plant. (Livingston, Field Crop Production, The Macmillan Company) 243
58. Field pea. (Piper, Forage Plants, The Macmillan Company) . 244
59. Cowpea. (Piper, Forage Plants, The Macmillan Company) . . 245
60. A soybean plant. (Livingston, Field Crop Production, The Macmillan Company) 246
61. Hairy vetch. (Piper, Forage Plants, The Macmillan Company) 247
62. Timothy. (Piper, Forage Plants, The Macmillan Company) . 248
63. Production of timothy in the United States. (Hitchcock, A Textbook of Grasses, The Macmillan Company) . . 249
64. Common millet. (Voorhees, Forage Crops, The Macmillan Company) 250
65. German millet. (Voorhees, Forage Crops, The Macmillan Company) 251
66. Hungarian millet. (Voorhees, Forage Crops, The Macmillan Company) 251
67. A field of Sudan-grass. (Piper, Forage Plants, The Macmillan Company) 252
68. Red top. (Livingston, Field Crop Production, The Macmillan Company) 253
69. Orchard-grass. (Piper, Forage Plants, The Macmillan Company) 254
70. Bermuda-grass. (Piper, Forage Plants, The Macmillan Company) 255
71. Field of orange sorghum. (Voorhees, Forage Crops, The Macmillan Company) 258
72. A field of black-hulled white kafir. (Duggar, Southern Field Crops, The Macmillan Company) 259
73. Field of milo. (Montgomery, The Corn Crops, The Macmillan Company) 260
74. Showing seed per acre, approximate time of planting and feeding different soiling crops. (Illinois Experiment Station) . 269
75. Field of velvet beans. (Duggar, Southern Field Crops, The Macmillan Company) 275
76. A field of oats and peas. (Voorhees, Forage Crops, The Macmillan Company) 276
77. Panicles of Canada blue grass and Kentucky blue grass. (Piper, Forage Plants, The Macmillan Company) 279

FIGURE PAGE
78. Brome-grass. (Piper, Forage Plants, The Macmillan Company) 282
79. Hogging down corn. (Iowa Experiment Station) 284
80. Meadow-fescue. (Piper, Forage Plants, The Macmillan Company) 285
81. Mangels. (Cornell Experiment Station) 297
82. Sugar beet. (Livingston, Field Crop Production, The Macmillan Company) 298
83. Carrots. (Cornell Experiment Station) 299
84. Rutabagas. (Cornell Experiment Station) 300
85. Cassava. (Duggar, Southern Field Crops, The Macmillan Company) 301
86. Hogs in rape. (Missouri Experiment Station) 302
87. Kohlrabi. (Cornell Experiment Station) 303

INTRODUCTION

Any study of scientific agriculture should include a study of stock feeding, inasmuch as 15 per cent of the total farm capital of this country is invested in farm animals, and all these animals must be fed. According to the United States Department of Agriculture there are 25,000,000 horses and mules, 59,000,000 cattle, 52,000,000 sheep, and 65,000,000 hogs in the United States. 77.6 per cent of the corn crop, 59.0 per cent of the oats crop, 32.5 per cent of the barley crop, and 80.0 per cent of the hay crop are fed to animals on the farm. These figures do not take into consideration the animals of the cities, The value of these crops is something over $2,270,000,000. or if one includes the horses of the cities, the total feed bill of this country is at least $2,500,000,000 per year exclusive of the enormous amounts of money spent for commercial feeds not grown on the farm, such as bran, cottonseed meal, etc. All together the animals of the United States produce about $5,000,000,000 worth of products yearly, — a sum nearly as great as the value of our total crops.

No matter what phase of agriculture a man expects to make his life work, whether he is a dairyman, a live stock farmer, an orchardist, a grain farmer, or a market gardener, he is certain to need at least a general knowledge of the feeding of farm animals. There is no type or system of agriculture which does not necessitate the use and, consequently, the feeding of some animals. To the specialist in animal or dairy

husbandry, a knowledge of the best feeding practices is of utmost importance.

Within recent years many factors have arisen so affecting the live stock industry that it is imperative that the successful breeder and feeder must have an intimate knowledge of the fundamental, scientific principles underlying the art of stock feeding. The great increase in the value of farm land, especially in the corn-belt, the gradual disappearance of the range, and the consequent increase in the value of feedingstuffs and of live stock require that the stockman take advantage of every aid which science and experience offer in order to make his business a financial success.

There is, in many cases, a large waste in the feeding of our farm animals. Many of our good farmers are feeding rations which although giving good results are not as economical as others which would give the same results; others do not obtain the best results although they feed a more expensive ration. Greater efficiency and greater economy in a great many cases will result from the application of a few general scientific principles.

New or unfamiliar crops, as alfalfa, cowpeas, soybeans, sweet clover, rape, Sudan-grass, etc., necessitate a wider knowledge of feeding values. Also the successful feeder must have a knowledge of the feeding values of commercial feeds and by-products from the manufacture of human foods, as tankage, beet pulp, distillers' grains, the oil meals, etc. One or two generations ago the feeds commonly used for live stock were usually restricted to the grains and roughages grown on the farm. However, with the great increase in the value of land, farm animals, and farm crops, knowledge of the feeding value of the farm crops is not sufficient, but the feeder must also be familiar with the feeding value and general adaptability of

the large number of by-products on the market, especially as these feeds vary considerably in price and even more in nutritive value. Most economical feeding is therefore only possible when the relative values of these purchased feeds and the farm grown feeds are clearly understood. Oftentimes a man can sell to good advantage a part of the feeds produced upon the farm and buy commercial feeds for his live stock. On the other hand many farmers buy commercial feeds at prices much above their true value. Also the manures from some feeds have a much higher fertilizing value than the manures from others, thus necessitating a knowledge of the fertilizing values of feedingstuffs.

A partial solution to the problem of the "high cost" of living may be found in rational stock feeding. A large part of our farm crops are unfit for human food. However, by feeding these rough feeds to meat or dairy animals, we may convert an otherwise useless product into the most nutritious of foods. Many farmers, especially west of Ohio, burn tons of corn stover and straw every year because there is no market for them and they have no live stock to eat them. As you will learn later, one-third of the feeding value of the corn crop is in the stover. However, the only way to recover that third and make it fit for human use is to feed it to animals and convert it into meat or milk, or wool. Our soil experts tell us that in order to maintain the fertility of our soil economically we must introduce a legume into the crop rotation. To do this and make the most profit from our land, we must keep live stock in order to convert the roughage of the rotation into human food.

THE PRINCIPLES OF FEEDING FARM ANIMALS

CHAPTER I

THE CHEMICAL COMPOSITION OF FEEDINGSTUFFS

In order for the student of stockfeeding to acquire a thorough understanding of the subject, it is necessary for him to have a general knowledge of the chemical composition of feedingstuffs. The composition of feedingstuffs is quite variable, and their feeding value depends to a large extent upon their composition. When asked concerning the value of a feed with which one is unfamiliar, one usually refers to its chemical composition, although other factors also have considerable influence, as will be explained later.

Elements. — Chemistry teaches that all vegetable and animal substances are composed ultimately of chemical elements. Of the 83 chemical elements now known, apparently only 12 are of importance from the standpoint of stockfeeding. These are as follows: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, sulphur, sodium, magnesium, chlorine, and iron.[1] Other elements,

[1] Dr. C. G. Hopkins, in "Soil Fertility and Permanent Agriculture," presents the following memory key to the elements essential to plant life: "C. HOPK'NS' CaFe, Mg," if "Mg" stands for "mighty good" and "I" is omitted for modesty. If the student then remembers that all animals require salt, NaCl, he has a list of the important elements.

as iodine, fluorine, silicon, aluminium, copper, arsenic, and manganese, often occur in small amounts in plant and animal life, but they are not of sufficient importance in this connection to warrant their further mention.

Compounds. — Although vegetable and animal substances consist primarily of chemical elements, these elements, with the exception of small amounts of oxygen and nitrogen, do not exist in the plant or animal in the free, elemental state, but they occur in combination with one another to form compounds, such as sugar, starch, fat, and water. The compounds which occur in plant and animal life are large in number and vary considerably in their chemical composition, their properties, and their nutritive values. In fact, these compounds are so numerous and varied that the chemist has attempted to simplify their discussion by dividing them into five classes, putting all compounds of similar composition, properties, and nutritive value into the same class. These classes are as follows: (1) water, (2) mineral matter or ash, (3) crude protein, (4) carbohydrates, and (5) fats. The first two classes are incombustible, and are called inorganic compounds, while the last three classes are combustible, and are called organic compounds.

Nutrients. — These classes of compounds often are spoken of as nutrients. Although the term is used rather loosely, a nutrient may be defined as any feed constituent or group of constituents of the same general chemical composition that is capable of liberating energy or serving for the production of tissue in the animal body. In other words, it is any feed constituent or group of constituents which may aid in the support of animal life. Thus water, mineral matter, crude protein, carbohydrates, and fats are usually regarded as the nutrients of feedingstuffs.

The elementary composition of these classes of compounds or nutrients is shown in the following diagram, which is a modification of a similar diagram presented by Jordan.[1]

- All vegetable and animal matter
  - Inorganic compounds
    - Water
      - Hydrogen
      - Oxygen
    - Ash or mineral matter
      - Oxygen
      - Sulphur
      - Phosphorus
      - Carbon
      - Chlorine
      - Sodium
      - Potassium
      - Calcium
      - Magnesium
      - Iron
  - Organic compounds
    - Crude protein
      - Carbon
      - Hydrogen
      - Oxygen
      - Nitrogen
      - Sulphur[2]
      - Phosphorus[3]
    - Carbohydrates
      - Carbon
      - Hydrogen
      - Oxygen
    - Fats
      - Carbon
      - Hydrogen
      - Oxygen

The average chemical composition of feedingstuffs is given in Table 28 of the Appendix.

WATER

Water, composed of the elements hydrogen and oxygen, is present in variable amounts in all vegetable and animal substances. It forms a large portion of the weight of such

[1] "The Feeding of Animals," p. 30. [2] Generally. [3] Sometimes.

substances as green plants, fresh meats, and milk, and in many cases it can be detected by sight and touch. Even substances like starch, bran, wood, straw, and corn, which appear to be quite dry, usually contain from 2 to 15 per cent of water. The water content of plants depends upon the species, the degree of maturity, and the amount of moisture in the soil. Thus fresh timothy grass contains about 60 per cent of water, while mangels contain 90 per cent; immature plants contain more water than mature ones; and plants grown in a moist soil contain more than those grown in a dry soil. Water in the plant acts as a solvent for the different forms of plant food and transfers them from one part of the plant to another. It also aids in imparting firmness and rigidity to the plant. This function is illustrated well by the withering of a plant when its water is removed by evaporation or drying.

Water in Feedingstuffs. — The stock-feeder should have a knowledge of the moisture content of feedingstuffs for at least two reasons: first, the amount of dry substance in a feed largely determines its nutritive value; consequently in using feeds which contain large amounts of water, as silage, wet beet pulp, milk, wet brewers' grains, and mangels (stockbeets), one must feed a larger amount than when using feeds which are low in moisture content in order to supply the same amount of dry matter. Second, the keeping qualities of feeds depend largely upon their low water content. Such feedingstuffs as the hays, grains, meals, and oil cakes, when stored in bulk, are very liable to ferment or mold if they contain more than 18 to 20 per cent of moisture. This usually injures their quality and decreases their nutritive value.

The amount of moisture in a feedingstuff is determined in the chemical laboratory by drying a weighed sample of the feed in a drying oven at a temperature of 212° F. until all the water is driven off. The dried sample then is weighed, the loss in weight representing the amount of water driven off. The percentage of water is obtained by dividing the original weight of the sample into the weight of the water, and multiplying the result by 100.

TABLE 1. — PERCENTAGES OF WATER IN THE DIFFERENT CLASSES OF FEEDINGSTUFFS [1]

Oil by-products	7 to 11	Leguminous hays	9 to 15
Packinghouse by-products	7 to 11	Stovers and fodders	8 to 40
Oil-bearing seeds	8 to 9	Grass pastures	62 to 80
Cereal by-products	6 to 12	Silage	70 to 80
Cereal grains	10 to 12	Leguminous pastures	70 to 85
Straws	7 to 16	Roots	86 to 91
Grass hays	7 to 15	Milk and milk-products	87 to 94
Leguminous seeds	7 to 12		

Table 1 shows the average percentages of water occurring in the different classes of the common feedingstuffs. The data of this table show that the amounts of water in the different classes of feedingstuffs are quite variable. Milk and the root crops contain the largest amounts of water, — 86 to 94 per cent. Pastures and silage also contain large amounts, — 62 to 85 per cent. Stover and fodder contain from 8 to 40 per cent water. The amount may vary considerably, depending largely upon the method of curing. The hays, straws, and legume seeds all contain medium amounts of water, — 7 to 16 per cent, while the cereal

[1] These values represent the upper and lower limits of the average water content of the common feedingstuffs included under each class. For an explanation of this classification of feedingstuffs, see Chapter IX.

grains and oil-bearing seeds, and their by-products, and the packinghouse by-products contain the smallest amounts of water, — 7 to 12 per cent.

MINERAL MATTER OR ASH

The mineral matter or ash, as the name implies, is that part of the feed which remains after the combustion of the organic substances. Common ashes are an impure form of mineral matter. The ash consists principally of the elements, potassium, calcium, magnesium, iron, and sodium, in the form of oxides, phosphates, sulphates, carbonates, and chlorides. However, the elements or radicles found in the ash are not necessarily in the same form or combination as those occurring in the living organism. In the unburned substance, some of these elements may occur in different inorganic combinations with each other, or in combination with organic substances. Thus sulphur occurs in many of the proteins, phosphorus occurs in some of the proteins and in other organic substances, and calcium often occurs in combination with organic acids. During the combustion of the feed the organic material is oxidized and driven off, leaving behind these elements in inorganic combination. Further, nitrates and nitrites occur in small quantities in growing plants and in animals, but by ignition in the preparation of the ash these acid radicles are decomposed and driven off while the metals of these salts are combined with other acid radicles.

No parts or products of either plant or animal life are free from mineral matter. It is an essential constituent of both plants and animals. The mineral elements potassium, calcium, magnesium, iron, oxygen, phosphorus,

and sulphur are necessary for the proper growth and development of all agricultural plants and, in addition to these elements, sodium and chlorine are essential also for the nutrition of agricultural animals.

The Mineral Constituents in Feedingstuffs. — In feedingstuffs, potassium is found in greatest amounts in the roughages, as corn stover, hays, and straws. Fairly large quantities are found in the oil by-products, in wheat bran, in milk, in tankage, and in malt sprouts, while the ordinary cereal grains are deficient in this element.

Calcium is especially abundant in bone meal, tankage, and leguminous hays, while the ordinary grains and many of their by-products are deficient. The rations of young growing animals and of dairy cows are liable to be deficient in this element.

Magnesium is most abundant in the oil by-products and in wheat bran. It also occurs in considerable quantity in the legume hays and in the ordinary grains. The straws and roots are especially low in this element.

The quantity of iron in feedingstuffs is very small in all cases, but it is probably always sufficient except under pathological conditions.

The air is the source of the oxygen to the animal body.

Phosphorus occurs abundantly in bone meal, tankage, bran, middlings, oil by-products, and legume seeds. The grains and legume hays contain medium amounts of this element, while dried blood, gluten meal, roots, and straws contain only small amounts. The rations of the young growing animal and of the dairy cow are apt to be deficient in phosphorus.

Sulphur probably is found in small but sufficient quantities in all feedingstuffs.

Sodium and chlorine must be furnished to nearly all animals in the form of sodium chloride or common salt, as the ordinary feedingstuffs do not supply these elements in sufficient amounts.

The amount of mineral matter or ash in a feedingstuff is determined by igniting a weighed sample of the feed until all organic matter has disappeared. The residue is ash or mineral matter. The weight of the ash divided by the original weight of the sample, and multiplied by 100, gives the percentage of mineral matter.

TABLE 2. — PERCENTAGES OF MINERAL MATTER IN THE DIFFERENT CLASSES OF FEEDINGSTUFFS [1]

Milk and milk products	0.4 to 0.8	Oil-bearing seeds	2.6 to 4.3
Roots	0.8 to 1.2	Straws	3.2 to 5.8
Silage	1.1 to 2.8	Stovers and fodders	3.7 to 12.0
Grass pastures	1.0 to 2.8	Cereal by-products	1.0 to 6.2
Cereal grains	1.4 to 3.0	Oil by-products	4.0 to 6.7
Leguminous pastures	1.3 to 3.5	Grass hays	3.9 to 7.9
Leguminous seeds	2.6 to 5.4	Leguminous hays	6.7 to 10.7
		Packinghouse by-products	4.1 to 64.4

Table 2 shows the average percentages of mineral matter in the different classes of feedingstuffs. This table shows that the packinghouse by-products are quite high in ash content, — 4.1 to 64.4 per cent. Especially is this true of bone meal and tankage, meat scrap and blood meal being only fairly high. Leguminous hays contain fairly large amounts, — 7 to 11 per cent, as also do the non-legume hays, the oil and cereal by-products, the straws, the oil-bearing seeds, and the legume seeds, — 2 to 8 per cent.

[1] These values represent the upper and lower limits of the average content of mineral matter of the common feedingstuffs included under each class.

As a rule, the cereal grains, silage, and roots, are quite low in ash, — 1 to 3 per cent.

CRUDE PROTEIN

Crude protein includes all the substances of the plant or animal which contain the element nitrogen. In general, crude protein consists of two sub-classes of substances: (1) proteins, often called true protein, and (2) non-proteins, which is an abbreviation for "non-protein nitrogen-containing substances."

Proteins. — In every living organism there are present highly complex, nitrogen-containing compounds to which the general name proteins has been given. These substances form the chief part of the solid matter of the blood, muscles, nerves, glands, and organs of the animal, and occur in smaller amounts in every part of plants, but especially in the seeds. They form an essential part of the protoplasm of every cell, plant or animal. They also are important constituents of the cell wall of all animal cells, and are always present in the fluids which surround the cell. As a nutrient, the proteins occupy an important position, due to the fact that they are the only nutrient which contains nitrogen in forms available to the animal body. Thus, they are necessary not only for the growth and development, but also for the life, of every animal. Water, mineral matter, and protein are absolutely essential constituents of the rations of all animals. An animal soon dies if water, mineral matter, or protein is withheld from the ration. If an insufficient amount of any of these nutrients is given, the animal fails to develop properly, and in extreme cases dies.

The proteins are composed of the elements carbon, hydrogen, oxygen, nitrogen, and usually sulphur in varying proportions. Some proteins also contain phosphorus, while other elements are found sometimes. The typical protein molecule usually contains from 15 to 19, or an average of 16 per cent of nitrogen, 52 per cent of carbon, 7 per cent of hydrogen, 22 per cent of oxygen, and 0.5 to 2 per cent of sulphur. The chemical structure of the protein molecule is very complex, and neither the formulæ nor molecular weights of any of the proteins have been determined definitely. An idea of their complex nature may be obtained from the following approximate formulæ of some common proteins: egg albumin, $C_{696}H_{1125}N_{175}S_6O_{220}$; serum albumin, $C_{694}H_{1045}N_{175}S_2O_{225}$; oxyhemoglobin, $C_{656}H_{1161}N_{207}S_2FeO_{210}$.

However, it has been determined that the complex proteins are made up of *amino acids*, which are comparatively simple organic acids in which one or two "amino," or NH_2 groups are substituted for an equal number of hydrogen atoms. There are 18 or more of these amino acids known. Some of them occur in all proteins; others are absent, or are present in only small amounts, in certain proteins. Furthermore, different proteins may be formed from the same amino acids arranged in different combinations. Thus one finds that the proteins are very numerous. The amino acids have been compared to the letters of the alphabet. "When they are arranged together they can make many different proteins just as there are many different words in the dictionary."[1]

There are considerable differences in the nutritive values of the different amino acids, some of them being essential

[1] Lusk, "The Basis of Nutrition," p. 17.

to life itself, while others are essential to growth only. Therefore different proteins may differ considerably in nutritive value. For example, an animal will starve to death on the protein, gelatin, because it is lacking in two of the amino acids which are essential to the animal organism, viz., tyrosine, and tryptophane. Another example is zein, the principal protein of corn, which is lacking in two essential amino acids, lysine and tryptophane. Consequently, in practical feeding it is well that the feeder should know something about the amino acid content of the proteins in order to make sure that he is providing the proper kind as well as the proper amount of protein in the ration.

Non-proteins. — The non-proteins are substances which contain the element nitrogen but which are not proteins. In most cases, the non-proteins are simply proteins in the process of formation or decomposition. They consist, principally, of amino acids, amides, ammonia, and other compounds, which nature ultimately would build up into the complex proteins; or else they are the products of complex proteins which have been decomposed and broken down with the formation of amino acids and other simpler substances. Thus non-proteins are especially abundant in immature plants, where the protein formation has not been completed, and in fermented feeds, as silage, where the proteins have been decomposed partially. Ripe grains are comparatively low in them. The nutritive value of a proper mixture of the non-proteins is equal to that of the true proteins. However, if they are not present in the proper proportions, the non-proteins will not be as valuable as most proteins.

Crude Protein in Feedingstuffs. — In the ordinary analysis of feedingstuffs, the proteins and the non-proteins are not determined separately, but they are determined together as crude protein. The chemical determination of crude protein is based upon the fact already noted, that proteins contain an average of 16 per cent of nitrogen. Thus to determine the amount of crude protein in a feedingstuff, *the amount of total nitrogen in a weighed sample is found* and then multiplied by 6.25 to obtain the amount of crude protein in the sample. (If 16 per cent of the weight of protein consists of nitrogen, to find the weight of the total protein, one multiplies the weight of the nitrogen by the number of times 16 per cent is contained in 100 per cent, or by 6.25.) *The calculated weight of the crude protein,* divided by the weight of the sample and multiplied by 100, gives the percentage of crude protein in the sample.

Crude protein usually is the most expensive nutrient to buy or produce and the one most often lacking in farm rations, especially in the corn-belt, where corn is the principal crop. Table 3 shows the average percentages of crude protein in the different classes of ordinary feedingstuffs. The packinghouse by-products, as dried blood, tankage, and meat scraps, contain the largest amounts of crude protein, — 24 to 84 per cent. Then follow in approximately the order named, the various oil by-products, — 18 to 45 per cent; leguminous seeds, — 20 to 36 per cent; the oil-bearing seeds, — 16 to 23 per cent; the cereal by-products, — 10 to 31 per cent; and the legume hays, — 13 to 19 per cent. The cereal grains are only medium in protein content, — 9 to 12 per cent. The non-leguminous hays, straws, fodder, stover, fresh grasses, silage, and roots contain the

smallest amounts of crude protein, in most cases ranging from 1 to 7 per cent.

TABLE 3. — PERCENTAGES OF CRUDE PROTEIN IN THE DIFFERENT CLASSES OF FEEDINGSTUFFS [1]

Roots	1 to 2	Cereal grains	9 to 12
Silage	1 to 3	Leguminous hays	13 to 13
Grass pastures	1 to 3	Cereal by-products	10 to 19
Milk and milk-products	3 to 4	Oil-bearing seeds	16 to 23
Straws	3 to 9	Leguminous seeds	20 to 36
Leguminous pastures	3 to 5	Oil by-products	18 to 45
Stovers and fodders	4 to 13	Packinghouse by-products	24 to 84
Grass hays	5 to 9		

CARBOHYDRATES

The carbohydrates are of very great importance to plant life. They are the most abundant constituent of the vegetable kingdom. They not only make up the cell walls of the plant, but it is in the form of carbohydrates that most plants store up reserve food material in the cell itself. They are present also in very minute amounts in many animal tissues in the form of *glycogen* or *animal starch*. Glycogen is found in largest amounts in the liver. A small amount of the sugar glucose is usually found in the blood and muscles. Carbohydrates are the most abundant nutrient in most feedingstuffs, which fact, together with their relative cheapness, makes them of especial importance to the stock-feeder.

Familiar forms of the carbohydrates are *glucose* or *grape sugar*, *sucrose* or *cane sugar*, *lactose* or *milk sugar*, the *starches*, as *corn*, *wheat*, and *potato starch*, and *cellulose* or *vegetable fiber*.

[1] These values represent the upper and lower limits of the average crude protein content of the common feedingstuffs included under each class.

All carbohydrates are composed of the three elements carbon, hydrogen, and oxygen, the two latter generally being in the proportion to form water (*i.e.* there are twice as many atoms of hydrogen as of oxygen in the molecule), from which the name, carbohydrate, is derived. Thus the chemical formula of glucose is $C_6H_{12}O_6$, of sucrose, $C_{12}H_{22}O_{11}$, and of starch, $(C_6H_{10}O_5)_n$. As indicated by these formulæ, some of the carbohydrates are comparatively simple compounds, others are more complex, while still others are very complex. *Glucose* or *grape sugar* and *fructose* or *fruit sugar* are the simplest carbohydrates of importance. They are represented by the chemical formula, $C_6H_{12}O_6$. Sucrose or cane sugar, lactose or milk sugar, and maltose or malt sugar are more complex compounds as indicated by the formula $C_{12}H_{22}O_{11}$. The starches, celluloses, dextrins, etc., are complex carbohydrates, having the formula $(C_6H_{10}O_5)_n$, the n representing an unknown number. The pentosans are complex carbohydrates having the formula $(C_5H_8O_4)_n$. Under the proper conditions, the complex carbohydrates can be changed to the simpler forms. Further reference will be made to this fact under the discussion of the digestion of the carbohydrates.

On account of their difference in solubility and nutritive value, chemists usually divide the carbohydrates of feedingstuffs into two sub-classes, *nitrogen-free extract* and *crude fiber*.

Nitrogen-free Extract. — The nitrogen-free extract consists largely of starches and sugars, with small amounts of less important carbohydrates, such as the pentosans. Starch is the principal carbohydrate found in the nitrogen-free extract of most feedingstuffs. It is found especially in the

seeds of plants, as in the cereal grains. The sugars are found principally in the stem and roots of certain plants, as in sorghum and sugar beets.

In addition to the carbohydrates, the nitrogen-free extract usually contains small amounts of organic acids and other substances which are not carbohydrates. Especially is this true in the case of fermented feeds, such as silage. The organic acids and other substances, owing to their small amounts, possess only a small nutritive value, but they may have an important indirect influence upon the value of a feed by increasing or decreasing its palatability, or through some special physiological effect.

Nitrogen-free Extract in Feedingstuffs. — The percentage of nitrogen-free extract in a feedingstuff is obtained by adding together the percentages of water, mineral matter, crude protein, fat, and crude fiber, and subtracting the total from 100.

Nitrogen-free extract is the most abundant and the cheapest nutrient produced in the corn-belt. The cereal grains contain the largest amounts of nitrogen-free extract, — 60 to 75 per cent, although the root crops, when calculated on the water-free basis, also contain large amounts. The by-products of the cereal grains contain considerable nitrogen-free extract, — 39 to 65 per cent. The legume seeds, the oil-bearing seeds and their by-products, and the hays, straws, fodders, and stovers, contain medium amounts, — 23 to 52 per cent. Green pasture grasses and silage contain small amounts, — 6 to 20 per cent, while the packinghouse by-products contain little or no nitrogen-free extract.

The average percentages of nitrogen-free extract in the various classes of feedingstuffs are given in Table 4.

TABLE 4. — PERCENTAGES OF NITROGEN-FREE EXTRACT IN THE DIFFERENT CLASSES OF FEEDINGSTUFFS[1]

Packinghouse by-products	0 to 4	Oil by-products	25 to 43
Milk and milk-products	4 to 5	Leguminous hays	31 to 44
Roots	5 to 7	Straws	23 to 47
Leguminous pastures	6 to 14	Grass hays	37 to 49
Silage	7 to 15	Stovers and fodders	30 to 52
Grass pastures	7 to 20	Leguminous seeds	14 to 58
Oil-bearing seeds	21 to 28	Cereal by-products	39 to 65
		Cereal grains	60 to 75

Crude Fiber. — Crude fiber is the tough, woody, fibrous portion of plants. It is made up principally of cellulose and other similar substances, together with some pentosans. Cellulose is composed of the elements carbon, hydrogen, and oxygen, and is one of the complex carbohydrates. It forms the groundwork of all vegetable tissues, the walls of all plant cells consisting of cellulose. Thus it is found in all parts of the plant as an essential constituent of every plant cell. It is seldom found pure in nature, except in the young and tender parts of plants, but usually it is impregnated more or less with lignin, which is a carbohydrate that is similar to, but harder and tougher than, cellulose.

The proportion of crude fiber in plants varies greatly with the species, size, and degree of maturity of the plant. As a rule, large plants contain more than small plants, and mature plants contain more than immature ones. In general, the hardness and toughness of large or mature plants are due to their increased content of crude fiber. Also the proportions of crude fiber in the different parts of the

[1] These values represent the upper and lower limits of the average content of nitrogen-free extract of the common feedingstuffs included under each [illegible]

same plant are greatly unlike. It is usually most abundant in the stem, with less in the foliage, and least in the seed. In the grains and seeds, the seed coats consist largely of cellulose, while but little is found in the interior. Cellulose is never found in the animal body.

Familiar forms of crude fiber are paper, made from the fiber of straw, flax, wood, or hemp; cloth, made from the fiber of cotton, flax, etc.; and rope, made from the fiber of hemp.

Crude Fiber in Feedingstuffs. — The crude fiber in feedingstuffs is determined by removing all other substances, in so far as possible, by boiling a weighed sample of the feed in dilute acid, then in dilute alkali, and then washing it with water, alcohol, and ether. The residue, consisting of crude fiber and ash, is dried and weighed. It is then ignited, and the ash is weighed. The weight of the ash deducted from the weight of the total residue represents the weight of crude fiber. The weight of the original sample divided into the weight of the crude fiber and multiplied by 100 gives the percentage of crude fiber in the feedingstuff.

The average percentages of crude fiber in the various classes of ordinary feedingstuffs are shown in Table 5. It is especially abundant in the husks of grains and seeds, as barley, oat, and cottonseed hulls, — 40 to 46 per cent, and in straws, hays, stover, and fodder, — 20 to 45 per cent. Inasmuch as the percentage of crude fiber is higher in mature than in immature plants, the late cut roughages contain more crude fiber than early cut roughages. The cereal grains and most of their by-products contain a relatively small amount, — 1 to 12 per cent, while feedingstuffs of

animal origin, as milk, dried blood, tankage, meat scraps, and bone meal, usually contain less than 4 per cent, unless they have been adulterated, as is sometimes the case.

TABLE 5. — PERCENTAGES OF CRUDE FIBER IN THE DIFFERENT CLASSES OF FEEDINGSTUFFS [1]

Milk and milk-products	none	Oil by-products	6 to 26
Roots	1 to 2	Cereal by-products	2 to 22
Packinghouse by-products	0 to 4	Grass pastures	4 to 12
Cereal grains	1 to 11	*Oil-bearing seeds*	*7 to 30*
Leguminous pastures	*4 to 8*	Stovers and fodders	15 to 29
Leguminous seeds	4 to 8	Leguminous hays	20 to 29
Silage	6 to 10	*Grass hays*	*25 to 36*
		Straws	36 to 45

FAT OR ETHER EXTRACT

The fats are distributed widely in both plant and animal life. They occur in nearly all plants, but in smaller amounts than the carbohydrates. They are found most abundantly in the seeds. Some plants, such as flax, cotton, the peanut, and the soybean, store their reserve food material in the seeds largely as fat, rather than as carbohydrates. In the animal, fats occur in almost every organ and cell. They are especially abundant in the fatty tissues of the abdominal cavity, in the subcutaneous tissues, and in the bone marrow. The animal body stores its reserve food mainly in the form of fat.

Chemically, fats are composed of the elements carbon, hydrogen, and oxygen. Compared with crude protein and carbohydrates, *fats are considerably richer in carbon and hydrogen and poorer in oxygen.* The average percentages

[1] These values represent the upper and lower limits of the average content of crude fiber of the common feedingstuffs included under each class.

of these elements found in the most abundant fats as compared with the percentages found in glucose, a carbohydrate, and with the average percentages found in the simple proteins, are as follows:

	CARBON	HYDROGEN	OXYGEN
Fats	76.5	12.0	11.5
Glucose	40.0	6.7	53.3
Proteins	52.0	7.0	22.0

On combustion, therefore, the fats are capable of liberating more energy than the carbohydrates and proteins. Consequently fats are of particular importance as a means of storing reserve food. About two and one-quarter times as much energy can be stored in a given amount of fat as in the same amount of carbohydrates.

Fats are compounds or salts formed by the combination of fatty acids and glycerin. Thus the fat, palmitin, is formed by the combination of glycerin and palmitic acid according to the following formula:

$$\underset{\text{Glycerin}}{C_3H_5\begin{cases}OH\\OH\\OH\end{cases}} + \underset{\text{Palmitic acid}}{\begin{cases}HO.CO.C_{15}H_{31}\\HO.CO.C_{15}H_{31}\\HO.CO.C_{15}H_{31}\end{cases}} = \underset{\text{Palmitin}}{C_3H_5\begin{cases}O.CO.C_{15}H_{31}\\O.CO.C_{15}H_{31}\\O.CO.C_{15}H_{31}\end{cases}} + 3\,H_2O$$

A fat which is liquid at ordinary temperatures is known as an oil. The most important animal fats are *stearin* and *palmitin*, which predominate in the more solid fats, as mutton and beef tallow; and *olein*, which predominates in the more liquid fats, as cod liver oil. These fats are also included in many vegetable fats. A great variety of other

fats are found in plants and animals. Among these the so-called drying and semi-drying oils are of interest, inasmuch as they have the power to dry and harden upon exposure to air, light, and moisture. This is especially true of the drying oils, of which linseed oil is the most important example. Consequently, the drying oils are used in painting. Cottonseed oil and corn oil are examples of semi-drying oils.

When a fat is heated with an alkali, such as caustic soda, the fat is broken up, setting the glycerin free, and the fatty acid is united with the metal of the alkali to form a soap. This process is called saponification. Advantage is taken of this property of fats in the manufacture of common soap on the farm, the alkali in the lye acting upon the fat of the animal refuse with the formation of soap. Potassium soaps are soft, while sodium soaps are hard. By treating a soap with mineral acid the soap is decomposed and the fatty acid is set free.

When exposed to the action of moisture, air, and light, fats gradually acquire a disagreeable odor, an acrid taste, and become acid in reaction. They are then said to be rancid. When ground feedingstuffs containing considerable fat, such as corn meal, soybean meal, oil meal, etc., are stored they gradually become rancid and consequently unpalatable to animals.

The *waxes*, such as *lanolin*, or wool fat, *beeswax*, and *sperm oil*, are closely related to the fats. They consist of combinations of fatty acids and some of the higher alcohols.

The *phosphatides*, also, are closely related to the fats. In addition to containing fatty acids and glycerin, they also

contain phosphoric acid and some nitrogen-containing compounds. They are found in the protoplasm of all cells. They occur most abundantly in the brain, nerves, heart, and blood corpuscles, in milk and eggs, and in the seeds of all the cereals. Although little is definitely known of their functions, yet they are among the most important substances in living matter, being essential components of all living cells.

Fat in Feedingstuffs. — The quantity of fat in a feedingstuff usually is determined by extracting a finely ground, dried, weighed sample of the feed with ether, which dissolves out the fat. The ether is then evaporated off and the residue of fat is weighed. The weight of the fat divided by the weight of the sample and multiplied by 100 gives the per cent of fat. However, not only fats, but other substances, such as waxes, chlorophyll, and some of the organic acids also, are extracted from the feedingstuff by the ether. This is true especially in the case of roughages, such as hay, fodder, and silage. Thus the extract is often spoken of as crude fat, or ether extract.

Of the feedingstuffs, the oily seeds, as flaxseed and cottonseed, and the waste animal products, as tankage and cracklings, contain the most fat, — 12 to 35 per cent. The oil by-products contain a medium amount, — 3 to 13 per cent. Of the ordinary grains, corn contains the largest amount, — 5.0 per cent. Non-leguminous hays, straws, roots, and the fresh pasture grasses contain the smallest amounts of fat, — 0.1 to 3 per cent.

The average percentages of fat or ether extract in the various classes of the ordinary feedingstuffs are shown in Table 6.

TABLE 6. — PERCENTAGES OF FAT IN THE DIFFERENT CLASSES OF FEEDINGSTUFFS [1]

Roots	0.1 to 0.4	Leguminous hays	1.9 to 5.2
Silage	0.3 to 2.2	Cereal grains	1.7 to 5.0
Leguminous pastures	0.4 to 1.1	Leguminous seeds	1.0 to 42.6
Grass pastures	0.3 to 1.3	Cereal by-products	1.3 to 10.6
Milk and milk-products	0.1 to 3.7	Oil by-products	2.7 to 12.6
Stovers and fodders	1.0 to 5.0	Packinghouse by-products	0.3 to 13.7
Straws	1.2 to 2.3	Oil-bearing seeds	20.0 to 34.0
Grass hays	1.3 to 3.0		

ACCESSORY SUBSTANCES IN THE RATION

Vitamines. — In their discussion of the question of the *vitamines in the diet, Osborne and Mendel* [2] have made the following statement: "The researches which have been devoted in recent years to certain diseases, notably beri beri, have made it more than probable that there are conditions of nutrition during which certain essential, but, as yet unknown, substances must be supplied in the diet if nutritive disaster is to be avoided. These substances apparently do not belong to the category of the ordinary nutrients, and do not fulfill their physiological mission because of the energy which they supply. Funk has proposed the name vitamine for the type of substance thus represented." But little is definitely known of the chemical composition and chemical properties of the so-called vitamines. However, it is known that certain substances, in addition to proteins, carbohydrates, fats, and mineral matter, are essential to proper nutrition. The disease beri beri in man is said to be caused by a diet of polished rice which

[1] These values represent the upper and lower limits of the average fat content of the common feedingstuffs included under each class.

[2] Jour. of Biol. Chem. XVI, 1913–1914, p. 423.

is deficient in certain of these unknown chemical compounds, the vitamines. Also beri beri may be caused by a diet of bread and macaroni from highly milled wheat flour. However, unpolished rice, or polished rice and rice bran, or whole wheat flour do not produce beri beri, indicating that the so-called vitamines are present in the outside coats of rice and wheat.

McCollum and Davis [1] fed mixtures of casein (a complete protein), carbohydrates, and mineral matter to young rats. Normal growth ensued for 3 to 4 months but then ceased. The addition to the ration of butter fat, egg-yolk fat, kidney fat (fat from the kidney itself, not the fat surrounding the kidney), fat from corn, or fat from wheat germ caused normal growth. However, the addition of lard, olive oil, cottonseed oil, or tallow did not add to the value of the basal ration. Later Osborne and Mendel [2] found that cod liver oil and the lighter oils of beef fat, added to the basal ration, produce normal growth, but they are not as efficient for this purpose as is butter fat, as larger amounts are required for normal growth.

Little or nothing is definitely known at this time as to the chemical composition, properties, and occurrence of these substances, or vitamines. However, they apparently play a very important rôle in nutrition.

It is difficult to say at the present time whether further knowledge of the vitamines will have any practical value in the feeding of farm animals. It is quite probable that it may, particularly in the case of hogs, where there ordinarily

[1] Jour. of Biol. Chem., XV, 1913, p. 167; XIX, 1914, pp. 245 and 373; XX, 1915, p. 641; XXI, 1915, p. 179; XXIII, 1915, pp. 181 and 231.

[2] Jour. of Biol. Chem. XVII, 1914, p. 401.

is not much variety in the ration. Such knowledge may help to explain why some feeds, such as wheat bran, have a nutritive value much higher than their gross chemical composition and energy values indicate. A study of the vitamines is certainly of practical importance in human nutrition and may shed further light upon the causes and remedies of such nutritional diseases as beri beri, pellagra, and scurvy.

CHAPTER II

THE CHEMICAL COMPOSITION OF FARM ANIMALS

THE animal body is the product of the feed which the animal consumes. Thus, having discussed briefly the different classes of compounds which are found in feedingstuffs, it is of importance to consider the composition of the animal body which is formed from them.

Although the chemical analysis of an entire animal is very much more difficult than the analysis of a feedingstuff, still considerable work has been done upon cattle, sheep, and hogs of different ages and degrees of fatness. Lawes and Gilbert, of the Rothamsted (England) Experiment Station,[1] carried on the first and most elaborate investigations upon the chemical composition of farm animals. They analyzed a fat calf, a half-fat steer, a fat steer, a fat lamb, a thin sheep, a half-fat sheep, an extra fat sheep, a thin hog, and a fat hog. Jordan, at the Maine Experiment Station,[2] analyzed two thin and two fat steers. Trowbridge, at the Missouri Experiment Station,[3] analyzed six thin steers. Emmett and Grindley, at the Illinois Experiment Station,[4] analyzed two thin pigs and five fat hogs. Haecker,[5] at the Minnesota Station, analyzed two new-born calves and forty-five steers

[1] Philosophical Transactions of Royal Society of London, 1859.

[2] Annual Report, 1895.

[3] Proceedings of the American Society for Animal Nutrition, 1910.

[4] Unpublished data.

[5] Proceedings of the American Society for Animal Production, 1914, and unpublished data.

in good condition, ranging in weight from 100 to 1500 pounds. Table 7 compiled from these results shows the average composition of the common meat-producing animals under varying conditions of fatness.

TABLE 7.—AVERAGE COMPOSITION OF MEAT-PRODUCING ANIMALS[1]

Animal	Condition	No. Analyzed	Water	Protein	Fat	Ash
			Per cent	Per cent	Per cent	Per cent
Calf	at birth	2	72.1	19.5	4.8	3.9
Calf	*fat*	1	63.0	15.2	14.8	7.0
Calf	good, 100 lb.	5	71.8	19.9	4.0	4.3
Calf	good, 200 lb.	4	69.5	19.6	6.3	4.6
Calf	good, 300 lb.	3	66.3	19.4	9.8	4.5
Calf	good, 400 lb.	5	65.8	19.3	10.6	4.4
Calf	*good, 500 lb.*	5	62.9	19.2	13.7	4.2
Steer	good, 600 lb.	3	62.0	19.2	14.0	4.6
Steer	good, 700 lb.	6	60.7	18.8	15.9	4.5
Steer	good, 800 lb.	4	57.9	18.7	19.2	4.2
Steer	good, 900 lb.	3	54.1	17.7	24.1	4.2
Steer	good, *1000 lb.*	2	53.0	17.6	25.5	3.8
Steer	good, 1100 lb.	1	48.0	16.2	31.9	3.9
Steer	good, 1200 lb.	2	48.6	16.6	31.1	3.7
Steer	*good, 1400 lb.*	1	47.8	16.1	32.6	3.5
Steer	good, 1500 lb.	1	43.5	15.7	37.7	3.2
Steer	very thin	1	69.2	21.0	2.2	7.0
Steer	thin	4	60.1	19.3	14.4	5.4
Steer	half-fat	4	56.4	17.6	19.1	4.8
Steer	*fat*	3	50.7	15.9	26.6	4.7
Lamb	fat	1	47.8	12.3	28.5	2.9
Sheep	thin	1	57.3	14.8	18.7	3.2
Sheep	half-fat	1	50.2	14.0	23.5	3.2
Sheep	fat	1	43.2	12.2	35.6	2.8
Sheep	very fat	1	35.2	10.9	45.8	2.9
Pig[2]	4 mos., thin	2	61.7	15.5	19.0	3.2
Hog	thin	3	59.5	14.9	20.5	3.0
Hog	fat	6	45.0	13.8	38.0	3.5

[1] Not including the contents of the stomach and intestines.
[2] Included also in the next average.

Water. — As shown by the table, water is an essential and abundant constituent of the animal body, varying in amount from 35 per cent in case of a very fat sheep to 72 per cent in case of the new-born calves. The blood, which forms from 3 to 10 per cent of the body weight, is 80 per cent water. The tissues, excluding the fatty tissues and the bones, contain from 50 to 85 per cent water, while the skeleton contains from 30 to 60 per cent water. In general, somewhat more than half of the weight of our farm animals consists of water. The percentage of water in the bodies of animals varies with their species, condition, and age. A study of the data presented in Table 7 shows that, in general, cattle contain more water than sheep and hogs. It shows further that fat animals contain considerably less water than thin animals of the same age and species. Other things being equal, the fatter the animal the smaller is the percentage of water which it contains. This explains in large part why pork and mutton usually contain less water than beef. The calves, the lamb, and the four-month-old pigs show a considerably higher water content than more mature animals of the same species. Other things being equal, the younger the animal, the more water it contains. This is shown very well by Figure 1, made by Professor Haecker from his results upon the composition of steers of different ages. It is a matter of common observation that veal and lamb contain more water than beef and mutton, respectively.

Mineral Matter or Ash. — The farm animals usually contain 3 to 5 per cent of mineral matter. By far the largest amount of mineral matter in the animal body is found in the bones, while smaller amounts occur in the protein tissues

and body fluids. Calcium is the most abundant constituent of the mineral matter of the body forming more than half of it. It is found especially in the bones in the form of phosphates. Phosphorus is found also in the active tissues, in the body fluids, and in some of the proteins and other complex compounds. Potassium is found especially in the lean tissues, as the muscles, organs, blood corpuscles, etc. Magnesium is quite generally distributed throughout the body. Sodium, in the form of sodium chloride, is found especially in the body fluids. Sulphur occurs in many of the proteins, especially in wool, hair, hoof, and horn. Inasmuch as the *fatty tissue contains only a small amount of mineral matter, the percentage of mineral matter in the animal body* varies inversely with the degree of fatness, *i.e.* fat animals contain a lower per cent of mineral matter than lean ones, and vice versa. Thus the percentages of mineral matter are less in hogs and sheep than in cattle, which ordinarily contain less fat.

Fat. — Under normal conditions fat occurs in nearly every organ and cell of the animal body. It is especially abundant in the connective tissues of the abdominal cavity, in the subcutaneous tissues, and in the bone marrow. Large quantities of fat may be stored by the animal as reserve food material. In fairly mature animals in good condition, fat next to water is ordinarily the most abundant substance of the animal body. Fat hogs usually contain about 38 per cent, fat sheep about 36 to 46 per cent, and fat steers about 24 to 38 per cent fat. Thin hogs and sheep contain about 20 per cent, and thin cattle about 14 per cent fat. The fat calf and the fat lamb contain less fat than more mature animals of the same species in similar condition. Other

things being equal, mature animals usually contain a larger per cent of fat than immature ones. In case of cattle this is clearly shown by Figure 1.

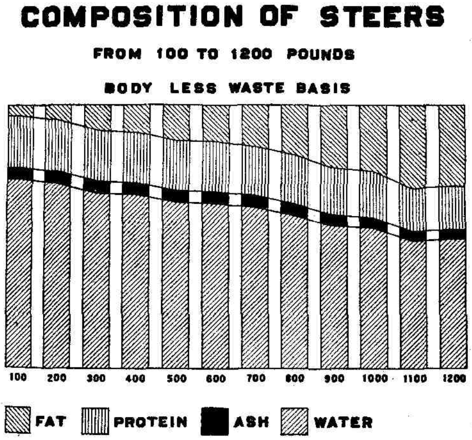

FIG. 1. — Composition of steers from 100 to 1200 pounds. (Minnesota Experiment Station.)

Protein. — As previously stated, proteins occur as an essential part of every animal cell, and in the fluids surrounding the cell. They form the chief part of the dry substance of the blood, muscles, nerves, glands, skin, hair, horns, and hoofs of the animal. In amount, protein usually ranks next to fat, although in very lean or in young animals

it may rank next to water. Fat cattle contain about 16 per cent, fat sheep about 12 per cent, and fat hogs about 14 per cent of protein. Thin cattle contain approximately 20 per cent, thin sheep about 15 per cent, and thin hogs about 15 per cent of protein. The fat calf and fat lamb contain about 20 per cent and 12 per cent of protein, respectively. In general, the fatter the animal, the lower is the per cent of protein. Thus cattle usually contain more protein than sheep and hogs. It may be noted also that the protein content of the animal varies directly with the water and ash content because considerable quantities of these two classes of compounds are always found associated with the proteins. As shown by Figure 1, the percentage of protein in the body decreases slightly with increasing maturity.

Carbohydrates. — The animal body contains a very small per cent of carbohydrates in the form of glycogen or "animal starch," as it is sometimes called. It is stored up especially in the liver which ordinarily contains from 1 to 4 per cent and in smaller amounts in the muscles. There is also a small amount of glucose in the blood and muscles. In the ordinary analysis of the animal body, the amount of carbohydrates is not determined.

Composition of Increase in Body Weight. — The feeding of meat-producing animals usually has as its primary object the increase of the body weight of the animal. The increase in body weight also is the primary object of feeding all growing animals. Gain in body weight is due ordinarily to one or both of two factors, growth and fattening.

Growth consists of an increase of the structural components of the body, chiefly by cell multiplication, resulting in a gain in size and weight. Inasmuch as the dry substance

of the structural components consists principally of protein material, growth may be defined as an increase in the protein tissue of the body. For the purposes of this book any tissue, the dry substance of which is composed largely of proteins, may be considered as protein tissue. It should be noted that any increase in protein is always accompanied by a large amount of water and a small amount of mineral matter. Any considerable fat production accompanying the increase in protein tissue may be regarded as incidental, its amount depending upon the amount and nature of the feed.

Fattening consists in the deposition of fat in the cells already present in the body, most largely in the cells of the loose connective tissue. During the process the cytoplasm and nucleus are pressed to one side and the cell wall may be greatly distended. The main object of fattening is not the storage of a large amount of fat for the nutritive value which the fat contains, but to improve the flavor, tenderness, and quality of the lean meat by the deposition of fat between the muscular fibers. This mixture of fat and lean is much desired by the butcher and consumer. It is known as "marbling." Figure 2 shows the desired marbling in a porterhouse steak from a prime steer carcass.

Just as the normal production of protein tissue during growth is accompanied by the production of more or less fatty tissue (*i.e.* tissue the dry substance of which is composed largely of fat) so also a fattening animal, unless quite mature, continues to grow while being fattened. Thus the two processes of growth and fattening shade into each other and no sharp distinction can be made between them, as in many cases both processes are taking place at the same time.

The chemical composition of the increase depends largely upon the proportion of growth to fattening. When the increase is due principally to growth, it consists largely of water and protein, together with a small amount of mineral matter. When the increase is due principally to fattening, *it consists largely of fat with only a small amount of water.*

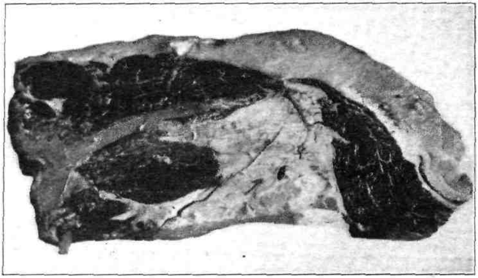

FIG. 2. — Porterhouse steak from a prime steer. Note the "marbling." (Illinois Experiment Station.)

Thus an increase in the weight of a calf, unless fed quite liberally, is due largely to a storage of protein and water together with a relatively small amount of fat. On the other hand, the gain in weight of a two-year-old steer is due largely to a storage of fat, with only a relatively small amount of water and protein. This is brought out quite clearly by the results of Waters, Mumford, and Trowbridge at the Missouri Station.[1] These investigators found that the

[1] Henry and Morrison, "Feeds and Feeding," p. 84.

chemical compositions of the first 500 pounds of gain and the second 500 pounds of gain by fattening steers were as follows:

	First 500 Pounds of Gain	Second 500 Pounds of Gain
	Per cent	*Per cent*
Water	37.6	17.8
Mineral matter	2.0	1.5
Fat	48.6	75.6
Protein	11.9	5.2

CHAPTER III

THE DIGESTION OF THE NUTRIENTS

In order that the nutrients of the feedingstuffs may be made available for the nutrition of the animal body, they first must undergo digestion. Digestion is the process by which the digestive agents change into forms which are soluble, diffusible, and available to the tissues such portions of the feed as are capable of such changes in the digestive tract. However, portions of the feed which are really capable of digestion often are not digested. Their escape may be merely a matter of chance.

The Digestive System. — The digestive system consists of the organs concerned in the reception and digestion of the feed, in the passage of the feed through the animal body, and in the excretion of the unabsorbed residue. For convenience in study, the digestive system may be divided into the alimentary canal and the accessory organs of digestion. The alimentary canal, or alimentary tract as it is often called, is the passage which begins with the *mouth*, includes the *esophagus, stomach, small intestine, large intestine,* and ends with the *anus*. These divisions are shown schematically in Figure 3.

The esophagus or gullet is the tube-like passage which leads from the mouth to the stomach. In the horse and hog the stomach consists of a single pear-shaped sac which has a capacity in the horse of 3 to 4 gallons and in the hog of

$1\frac{1}{2}$ to 2 gallons. The stomach of a horse is shown in Figure 4. In the ruminants or cud-chewing animals, as the cow and sheep, the stomach is modified considerably and much enlarged in order to handle the large amount of roughage which these animals ordinarily consume. The stomach of ruminants consists of four divisions, as follows: (1) the *rumen* or paunch; (2) the *reticulum* or honey comb; (3) the *omasum* or manyplies; and (4) the *abomasum* or true stomach. In cattle of medium size the stomach holds 30 to 40 gallons, in large animals, 40 to 60, and in small, 25 to 35. In mature cattle the rumen constitutes about 80 per cent, the reticulum 5 per cent, the omasum 7 or 8 per cent, and the abomasum 8 or 7 per cent of the total capacity of the entire stomach. In sheep the total capacity of the stomach is 4 to 5 gallons. The rumen or paunch is a very large sac used mainly for the temporary storage of the partially masticated feed. It connects directly with the reticulum and omasum, which are much smaller sacs. The reticulum and omasum besides connecting with the rumen and each other, also connect directly with the esophagus. The omasum has a great number of large, fleshy projections or leaves, resembling huge wrinkles upon the inside, from which it

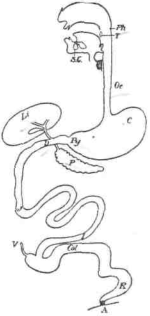

FIG. 3. — Digestive tract of man. (Paton, Veterinary Physiology.) *Ph* – pharynx; *T* – tongue; *S.G.* – salivary glands; *Oe* – esophagus; *c* – cardiac region of stomach; *Py* – pyloric region of stomach; *Li* – liver; *P* – pancreas; *D* – duodenum; *J* – jejunum; *I* – ileum; *V* – vermiform appendix; *Col* – colon; *R* – rectum; *A* – anus.

derives the common name, manyplies. The omasum connects directly with the abomasum or true stomach, which, although much smaller than the rumen, is considerably larger than the reticulum. The omasum and abomasum are about the same size. (See Figure 8.)

The small intestine is a long, folded, convoluted tube into which the stomach empties. The capacity of the small intestine of the different farm animals is approximately as follows: cow, 17 gallons; horse, 12 gallons; sheep, $2\frac{1}{2}$ gallons; and hog, $2\frac{1}{2}$ gallons. In the cow, the small intestine is about 130 feet long; in the horse, about 70 feet long; in the sheep, about 80 feet long; and in the hog, about 60 feet long.

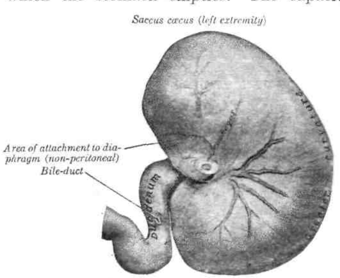

FIG. 4. — Stomach of the horse. (Sisson, Veterinary Anatomy.)

The large intestine joins the lower end of the small intestine. The upper end of the large intestine joining it to the lower end of the small intestine is called the *cæcum.* It is an elongated bag, the openings into and out of which are both found at the upper part close together. The relation of the cæcum to the small intestine is shown in Figure 5. The cæcum of the horse is much enlarged. It is 3 to 4 feet in length and has a capacity of 7 to 8

gallons. This provision enables the horse to handle considerable amounts of roughages. The large intestine is larger in diameter and is considerably shorter than the small intestine. It also contains many folds and convolutions, especially at its upper end. It ends in the anus. In the horse the upper end, just adjacent to the small intestine, is much enlarged to enable the animal to handle roughage. Owing to this provision, the large intestine of the horse has the greatest capacity of that of any of the farm animals, — about 30 to 35 gallons. The large intestine of the cow has a capacity of about 8 to 10 gallons, and that of the sheep about $1\frac{1}{2}$ gallons. The large intestine of the hog is relatively large, as this is the only provision it has for handling roughage. It has a capacity of about $2\frac{3}{4}$ gallons, or nearly twice that of the sheep. The length of the large intestine of the different farm animals is approximately as follows: horse, 25 feet; cow, 36 feet; sheep, 21 feet; and hog, 15 feet.

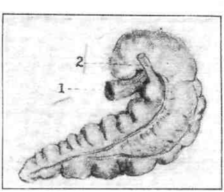

FIG. 5. — Cæcum of the horse. (Smith, Manual of Veterinary Physiology.) 1, The first colon of the large intestine; 2, the ileum of the small intestine.

The accessory organs of digestion are the *teeth*, *tongue*, *salivary glands*, *liver*, and *pancreas*. (See Figure 3.) The teeth are used in the mastication or chewing of the feed, while the tongue assists in conveying it into the mouth and in swallowing it after mastication. The salivary glands are small glands located under the ears, under the lower jaw, and between the branches of the lower jaw. They produce

the saliva and, by means of ducts, empty it into the mouth. The salivary glands of the cow are shown in Figure 6.

The liver, located just back of the stomach, is the largest gland in the body. It produces the bile which it stores in the gall bladder and, when needed, empties it into the upper part of the small intestine. It is of interest to note that the liver of the horse contains no gall bladder, the bile being stored in the ducts themselves.

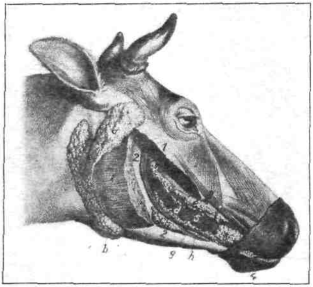

FIG. 6. — Head of cow, showing some of the salivary glands, *a, b, c, d, e, f, g, h.* (Sisson, Veterinary Anatomy.)

The *pancreas*, commonly called the sweet-bread, is a small gland which lies along the upper part of the small intestine. It secretes the pancreatic juice into the small intestine.

The relationship of the different parts of the digestive system, in case of the horse, is shown in Figure 7.

Enzymes. — Digestion is accomplished for the most part by means of substances known as *enzymes*, or ferments, which are formed by the salivary glands, by glands in the walls of the stomach, by the pancreas, and by glands in the walls of the small intestine. An enzyme may be defined as a substance secreted by cells, which has power, under

certain conditions, of bringing about a chemical reaction without itself entering into the composition of the final products of the reaction. In other words, an enzyme is a substance which, when added to certain inactive substances, causes a chemical change to take place with the formation

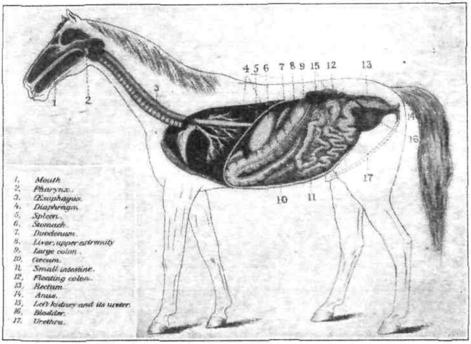

Fig. 7. — Digestive tract of the horse. (U. S. Department of Agriculture.)

of new products. The enzyme itself remains unchanged, and may be recovered entirely at the end of the reaction and used over and over again to produce similar reactions. It acts as a catalytic agent. Thus a dilute solution of starch may be allowed to stand at room temperature for a considerable length of time and no changes will take place. However, if a few drops of saliva, which contains the enzyme salivary amylase or "ptyalin," are added, all the starch

disappears within a few minutes and a sugar is formed in its place. If more starch then is added, it also is changed to sugar and the process may be repeated a great many times without using up or destroying the enzyme which brings about the change.

Enzymes are found in all plants and animals, and it is probable that not only digestion but many of the phenomena of life are brought about primarily by the presence of these substances. The ultimate purpose of the enzymes found in the digestive juices is to transform complex insoluble substances, as proteins, fats, and starch, into simple, soluble, transfusible substances which may be taken up by the blood.

Digestion in the Mouth. — The first step in the digestion of feedingstuffs is to tear and break them apart, and to reduce them to a fine condition. This is accomplished in the mouth by the process of mastication. The feedingstuffs are not only broken up, but they are also thoroughly mixed with the saliva, which is formed in large quantities by the salivary glands. The horse may secrete as much as 84 pounds, and the cow 112 pounds of saliva per day, the amount depending largely upon the dryness of the feeds. The main function of the saliva is to assist in mastication and swallowing, to stimulate the nerves of taste, and, in ruminants, to assist in rumination (*i.e.* chewing the cud). Saliva is slightly alkaline in reaction and, in most animals, contains the enzyme *salivary amylase* or ptyalin, which acts upon the starch of the feedingstuffs, finally changing it to maltose, or malt sugar, which is a much simpler carbohydrate than starch. Also, it is soluble in water. Salivary amylase acts best in a slightly alkaline or faintly acid solution

and is destroyed by more than a trace of acid. It is present in only small amounts in the saliva of cattle and sheep, and probably lacking in dogs.

In addition to salivary amylase, the saliva contains a small amount of *maltase*, an enzyme which changes maltose to the simple sugar glucose.

In ruminants mastication is usually quite incomplete at first but the food is later returned to the mouth for further mastication or *rumination*. At least seven out of every twenty-four hours are given to rumination. Inasmuch as an animal does not ruminate while working or sleeping, a hard-working ox may not have sufficient time in which to properly masticate his feed.

In the horse, mastication is usually quite complete when the feed is swallowed. In the pig, mastication is quite incomplete.

After the feed has been masticated, it is swallowed, passing by way of the esophagus or gullet into the stomach.

Digestion in the Stomach. — During and immediately following the entrance of the masticated feed, the entire contents of the stomach are neutral or slightly alkaline in reaction on account of the large quantity of saliva with which the feed is mixed. Thus salivary amylase and maltase may continue to act for some little time after the food reaches the stomach.

The gastric juice, secreted by glands in the walls of the stomach, begins to flow as soon as the masticated feed enters the stomach. As the gastric juice contains 0.2 to 0.5 per cent of hydrochloric acid, the contents of the stomach soon become acid. The acid destroys any salivary amylase which may have been acting upon the starch and the enzymes

of the gastric juice, *pepsin*, *rennin*, and *gastric lipase*, begin to act. Pepsin, in acid solution, acts upon the proteins and breaks some of them up into soluble substances known as proteoses and peptones which, although they are still proteins, are much less complex arrangements of amino acids. Proteoses are formed in larger amounts than peptones by peptic digestion. Rennin curdles milk by the precipitation of the casein. This prevents it from passing on through the alimentary tract undigested. The casein then is acted upon by the pepsin. Commercially, rennin is used in the manufacture of cheese. It is obtained from the stomachs of young calves.

The gastric juice also contains gastric lipase, an enzyme which splits up emulsified fats into glycerin and fatty acids. However, inasmuch as gastric lipase does not act upon unemulsified fats, its practical value in digestion is small.

Soon after the feed reaches the stomach, the muscular walls of the stomach begin a series of contractions, and the more liquid portion of the feed is squeezed out into the small intestine, while the more solid portion is retained for further action by the gastric juice.

Stomach digestion in the ruminants or cud-chewing animals differs from that in the horse and hog. When the feed is swallowed by a ruminant, the coarser particles enter the rumen, while the more liquid portion enters the reticulum, and passes through the omasum, into the abomasum or true stomach; or the finely masticated food may enter the omasum directly from the esophagus. The coarser particles may be returned from the rumen to the mouth and rechewed at the will of the animal. While in the rumen the food is

thoroughly mixed and the fibrous substances are mascerated and broken up by a slow churning movement. Also there is considerable digestion of the crude fiber, pentosans, and starch by means of bacteria which cause them to ferment, with the formation of lactic, acetic, and butyric acids, and carbon dioxide and methane gases. The acids may be utilized as food by the animal body, but the gases are useless and are excreted through the lungs and the digestive tract. However, the digestion of the cellulose sets free such nutrients as protein, starch, and fat which are inclosed in cells whose walls, as has been stated, are composed of cellulose. If the fermentation becomes too extensive and the gases are formed faster than they are removed from the body, as is often the case after large amounts of fresh grass are eaten, the animal "bloats."

The finer and more liquid part of the feed tends to accumulate in the reticulum, which regulates its passage into the abomasum. The reticulum also furnishes water to moisten the feed when it is regurgitated, and regulates its passage into the esophagus when it is returned to the mouth for rumination.

The food may find its way into the omasum either directly from the esophagus after remastication or from the rumen or reticulum. The main function of the omasum is to compress and break up any remaining coarse parts of the feed, which it does by crushing and rasping between its powerful, horny, muscular leaves. Its contents are always rather dry, as the liquid portion of the feed is squeezed out immediately and forced on into the abomasum or true stomach. The abomasum secretes the gastric juice whose enzymes act practically the same as in case of the horse and hog al-

ready described. The course of the food through the stomach of a ruminant is shown in Figure 8.

Digestion in the Small Intestine. — As a result of the digestion in the stomach, the food materials are reduced to an acid, semi-fluid, gray, pulpy mass, known as "chyme." In the upper part of the small intestine, the chyme is acted upon by three different digestive fluids, — the pancreatic juice, the bile, and the intestinal juice, which render it alkaline in reaction, and stop any further action by the pepsin upon the proteins.

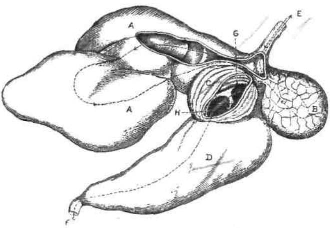

Fig. 8. — Stomach of a sheep, showing the course of the feed. (U. S. Department of Agriculture.) *A*, rumen; *B*, reticulum; *C*, omasum; *D*, abomasum; *E*, esophagus; *F*, pylorus.

The pancreatic juice is secreted by the pancreas (or sweetbreads), a gland which is located along the upper part of the small intestine. It contains the enzymes *trypsin*, *erepsin*, *pancreatic amylase* or *amylopsin*, *pancreatic lipase* or *steapsin*, and small amounts of *maltase*. *Sucrase* or *invertin* is sometimes found, while *lactase* is present in young animals. They act best in alkaline solution. Trypsin acts upon the proteins which the pepsin has not broken up, and also upon some of the proteoses and peptones formed by the previous action of the pepsin. Trypsin, however, carries the decomposition of the proteins further than does pepsin. It

not only produces proteoses and peptones, but in addition, it breaks up some of these compounds into peptids, which are still simpler combinations of only a few amino acids, and into the simple amino acids themselves.

Erepsin completes the action upon the proteins by breaking up the proteoses, peptones, and peptids into the amino acids. With the exceptions of casein, gelatin, fibrin, and a few other proteins, erepsin does not act upon the unchanged proteins, but only upon the products of their partial decomposition.

Pancreatic amylase acts upon the starch of the feed. Its action is much more pronounced than that of salivary amylase because it ordinarily has a longer time to act upon the food and is present in greater abundance. Like salivary amylase, it changes starch to maltose.

Lipase acts upon the fats of the feed, breaking them up into the fatty acids and glycerin of which they are composed. Most of the fatty acids then unite with the alkaline salts of the pancreatic juice and bile, producing soaps. (See page 20). The resulting soap solution, together with the bile, forms a fine emulsion with the remaining fats and enables the lipase to come in much closer contact with them and complete their digestion.

Maltase acts upon maltose with the formation of glucose. Sucrase acts upon sucrose with the formation of glucose and fructose, while lactase acts upon lactose with the production of glucose and galactose.

The bile is a yellowish-green, alkaline, very bitter liquid secreted by the liver and stored in the gall bladder, except in case of the horse as noted on page 38. It contains no enzymes, its chief digestive function being due to its solvent

action. It acts as a solvent of the fats and fatty acids and thus assists in their digestion and absorption. Its presence also increases the activity of some of the enzymes of the small intestine, particularly of pancreatic lipase.

The intestinal juice is secreted by small glands in the walls of the upper and middle part of the small intestine. It contains the enzymes, *erepsin, sucrase, maltase,* and *lactase.*

Erepsin is much more abundant in the intestinal than in the pancreatic juice. It acts upon the proteoses and peptones produced by the previous action of pepsin and trypsin upon proteins. It breaks them up further into the amino acids. Its action is the same as that of the erepsin of the pancreatic juice.

Sucrase acts upon sucrose or cane sugar, splitting it up into the simple sugars, glucose and fructose. Maltase acts upon the maltose formed by the action of salivary and pancreatic amylases upon starch. It splits it up with the formation of glucose. Lactase acts upon lactose or milk sugar, splitting it up into the simple sugars, glucose and galactose, the latter being quite similar to glucose.

In addition to the enzymes, the intestinal juice contains a substance called *enterokinase,* which has the property, when mixed with pancreatic juice, of enormously increasing the action of the latter on proteins.

Digestion in the Large Intestine. — When the contents of the small intestine pass into the large intestine, they still contain a certain amount of undigested and unabsorbed material. This remains in the large intestine for a considerable period of time during which the digestive processes started in the small intestine continue their action to a certain extent. In the large intestine of the hog and of the

horse, considerable digestion of the crude fiber may occur from bacterial actions similar to those already described as taking place in the rumen of cattle and sheep. Also, there is considerable bacterial action upon the undigested proteins, causing their putrefaction, with the formation of proteoses, peptones, amino acids, and numerous other products, as indol, skatol, amines, ptomaines, and hydrogen sulphide, which give to the feces their offensive odor, and which, in some cases, are toxic or poisonous to the animal organism if absorbed in large quantities. After remaining in the large intestine for some time, the undigested and unabsorbed feed residues, together with remains of the digestive juices, living and dead bacteria, and dead cells from the walls of the digestive tract are passed on into the lower part of the large intestine, or rectum, and excreted from the body through the anus as feces.

Absorption. — Absorption is the process by which the final products of the digestion of the feed are taken into the blood and lymph for final distribution to the tissues of the body. The greater part of the digested food material is absorbed from the small intestine, while smaller amounts are absorbed from the large intestine. The wall of the small intestine is lined with numerous, conical, round, or club-shaped projections known as *villi*, which extend out into the contents of the small intestine. Figure 9 shows a cross-section of the mucous membrane of the small intestine much enlarged. The partially digested food entering from the stomach is poured back and forth in the upper end of the small intestine in order to expose it sufficiently to the absorbing action of the villi. It is said that the contents of the small intestine of the horse are passed to and fro twenty

times before passing on to the large intestine. Each villus (singular of villi) contains a lacteal of the lymphatic system, surrounded by a net work of fine blood capillaries. Figure 10 shows the structure of a villus much enlarged. The

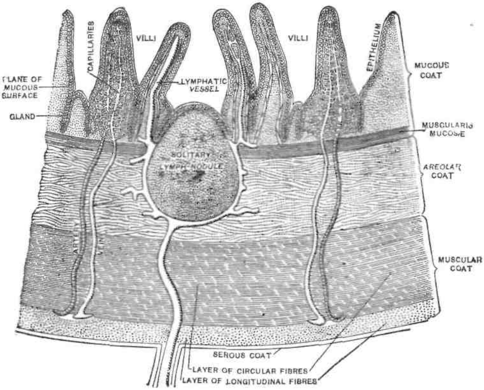

FIG. 9. — Cross section of mucous membrane of small intestine, showing capillaries and lacteals. (Jordan, Principles of Human Nutrition.)

products of the digestion of the proteins, *i.e.* amino acids, and of the starches and sugars, *i.e.* glucose and other simple sugars, pass into the capillaries, through the portal vein to the liver, and into the general circulation of the blood. The products of the digestion of crude fiber, *i.e.* salts of acetic and butyric acids, also are probably absorbed into the capillaries. In passing through the walls of the villi, the

soaps and glycerin formed in the digestion of the fats are recombined, forming fats again, and liberating the alkali of the soaps. The fats enter the lacteals instead of the capillaries and are carried into the lymphatic system, passing into the general circulation of the blood through the thoracic duct, which is located in the neck. Figure 11 shows the distended lacteals during absorption in case of the horse. The mineral matter of the feed is probably absorbed from the small intestine without any previous digestion, other than simple solution in the digestive juices.

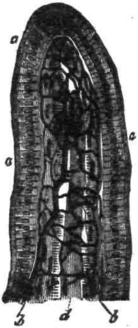

FIG. 10. — Longitudinal section of a villus, showing: *a*, epithelium: *b*, capillaries; *c*, lacteal. (Jordan, Principles of Human Nutrition.)

During the comparatively long time that the feed residues remain in the large intestine there is a marked absorption of water. There is also an absorption of some of the products of digestion by the enzymes carried in from the small intestine and of some of the products of bacterial fermentation and putrefaction. This takes place through the capillaries in the walls of the large intestine.

Concerning digestion, Mathews[1] makes the following statement: "In short, the main object of the whole process of digestion appears to be to resolve the various food substances into those common building stones, amino acids, monosaccharides (*i.e.* simple sugars, as glucose) and fatty acids, which are the common basis of all proteins, carbohy-

[1] "Physiological Chemistry," p. 446.

drates, and fats. Thus each organism can use these building stones in the proportion and order it needs to construct its own proteins and organized matter, which in each organism

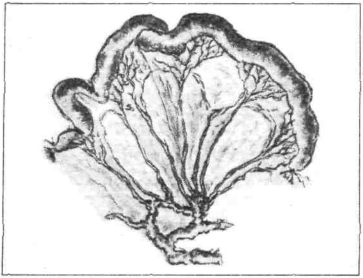

FIG. 11. — Loop of small intestine of the horse during active absorption showing distended lacteals. (Smith, Manual of Veterinary Physiology.)

has an architecture as distinct and characteristic as the form of the organism itself."

SUMMARY OF THE DIGESTION AND ABSORPTION OF THE NUTRIENTS

Inasmuch as the processes of digestion and absorption are so complex, it may assist the student to summarize the digestion and absorption of each individual class of nutrients.

Water. — Water, of course, needs no digestion. It is absorbed to a slight extent by the capillaries of the stomach and to a large extent by the capillaries of the villi of the small intestine, and by the capillaries of the walls of the large intestine.

Mineral Matter. — Mineral matter probably undergoes no digestion other than simple solution. It probably is absorbed principally from the small intestine.

Protein. — There is no action upon proteins in the mouth except mastication. They are first acted upon in the stomach by the pepsin of the gastric juice which, in acid solution, breaks up some of the complex proteins into the simpler and soluble proteoses and peptones. Rennin, in the gastric juice, coagulates the casein of milk, which is then acted upon by the pepsin.

Passing from the stomach into the upper end of the small intestine, the unchanged proteins, the proteoses, and the peptones encounter the more active enzyme, trypsin, of the pancreatic juice, and the enzyme, erepsin, of the pancreatic and of the intestinal juices. Trypsin, in alkaline solution, in the presence of the enterokinase of the intestinal juice, attacks the remaining proteins, breaking them down into proteoses, peptones, peptides, and the amino acids. It also attacks some of the proteoses and peptones previously formed by the peptic digestion, breaking them down still further into peptids and amino acids. The proteoses, peptones, and peptids are acted upon by the erepsin which, in alkaline solution, breaks them down further into the amino acids. Erepsin does not act upon unchanged protein, however, except in the cases of casein, fibrin, gelatin, and a few others. The amino acids, as they are formed, are absorbed by the villi of the small intestine into the capillaries and pass via the portal vein through the liver into the general circulation. Concerning the digestion and absorption of proteins, Underhill[1] makes the following statement: ". . . demolition

[1] "The Physiology of the Amino Acids," p. 34.

of the protein molecule is not of the nature of an explosion resulting in a large number of fragments scattered about, but instead it may be looked upon as a kind of slow erosion whereby certain projecting pieces are rubbed or broken off. . . . absorption takes place rapidly and the erosion products have a tendency to disappear from the alimentary canal."

Any proteins which have escaped digestion and absorption thus far are then passed on into the large intestine, where the action of the trypsin and erepsin may continue for some time. Here the proteins are attacked also by bacteria, and putrefaction takes place with the formation of the same products as formed in tryptic digestion, proteoses, peptones, peptids, and finally amino acids. The amino acids are attacked by bacteria, with the formation of such products as indol, skatol, amines, ptomaines, and hydrogen-sulphide, which, if absorbed in large quantities, may act as toxins to the animal organism. A part of the products of digestion in the large intestine is absorbed through the capillaries of the intestinal walls and passes via the portal vein through the liver into the general circulation. Any undigested or unabsorbed residues are excreted in the feces.

Nitrogen-free Extract. — Nitrogen-free extract consists of all the carbohydrates in the feedingstuff except those included under crude fiber. The principal constituent of the nitrogen-free extract of most feedingstuffs is starch. Of less importance is sucrose or cane sugar. Lactose or milk sugar is the principal constituent of the nitrogen-free extract of milk.

The first digestion of starch occurs in the mouth, where the salivary amylase, if present, acts upon some of the starch

with the production of maltose. The saliva contains also a small amount of maltase, which may change some of the maltose to glucose. These actions may continue after the masticated feed has reached the stomach, until it is rendered acid by the flow of the gastric juice. In case of ruminants, some digestion may take place in the rumen by fermentations, with the production of acetic and butyric acids, and carbon dioxide and methane gases. However, the principal digestion of starch takes place in the small intestine. Here the enzyme, pancreatic amylase of the pancreatic juice, acts upon starch, converting it to maltose. The enzyme, maltase, of the intestinal and of the pancreatic juices then acts upon the maltose, converting it to the simple sugar glucose.

Sucrase, another enzyme found in the intestinal and pancreatic juices, acts upon any sucrose or cane sugar, splitting it up into the simple sugars, glucose and fructose.

Lactase, the third sugar-splitting enzyme of the intestinal and pancreatic juices, acts upon lactose or milk sugar with the formation of the simple sugars glucose and galactose.

The starches and sugars are absorbed in the form of the simple sugars, glucose, fructose, and galactose, glucose being predominant. These sugars are absorbed by the villi of the small intestine and pass into the capillaries, through the liver, and into the general circulation of the blood.

Some digestion, both by enzyme action and by bacterial fermentation, may take place in the large intestine, the products of which are absorbed there by the capillaries.

Crude Fiber. — Crude fiber probably is digested only by the action of bacteria, as no special enzyme for the digestion of crude fiber or cellulose has been found. In ruminants,

the principal digestion of crude fiber occurs in the rumen or paunch, due to bacterial fermentation. This fermentation produces acetic and butyric acids, which may serve as nutrients to the animal body, and large quantities of carbon dioxide and methane gases, which in part are absorbed by the blood and excreted through the lungs, and in part are excreted directly by way of the alimentary tract.

Further fermentation of the crude fiber takes place in the large intestine, especially of the hog and of the horse, practically the same products being formed as in the paunch fermentation of the ruminants.

The acids thus formed unite with alkalies present to form salts, in which form they probably are absorbed into the capillaries of the small and large intestines. The undigested portions of the crude fiber pass from the body in the feces.

Fats. — Emulsified fats are acted upon in the stomach by the gastric lipase, which splits them up into glycerin and fatty acids. However, the unemulsified fats undergo little or no digestion until they reach the small intestine, where they are acted upon by the enzyme, lipase, of the pancreatic juice. This enzyme, in alkaline solution, splits up the fats into glycerin and fatty acids. The latter unite with the alkalies of the pancreatic juice and bile to form soaps. The solution of the soaps thus formed causes an emulsion to be formed with the remaining fats, enabling the lipase to come in closer contact with them. The bile aids in the digestion and absorption of fats by assisting in the solution of the fats, fatty acids, and soaps. The presence of bile also increases the activity of the pancreatic lipase.

The soaps, fatty acids, and glycerin are absorbed through the walls of the villi of the small intestine. In passing

through the walls the soaps are split up into the alkali and the fatty acids of which they are formed and the fatty acids reunite with the glycerin to form fat again. The fats pass into the lacteals and are carried into the lymphatic circulation and then through the thoracic duct into the blood.

CHAPTER IV

THE DIGESTIBILITY OF FEEDINGSTUFFS

From a nutritive standpoint, only those portions of the nutrients which are digested and absorbed are of value to the animal body. In a sense, food is not within the body until it enters the blood. The undigested portion of the ration, although it may be of value in distending the digestive tract and for other purposes, has no value as a means of support to the animal. Hence a knowledge of the amounts of the nutrients digested, and of the factors affecting the digestibility of the nutrients of the various feedingstuffs, is of considerable practical importance.

Coefficients of Digestibility. — The process of digestion in the farm animals usually is quite incomplete, the undigested portions of the ration being excreted in the feces. Thus the amount of a nutrient digested is equal to the amount of that nutrient consumed, less the amount of it excreted in the feces. The percentage of the nutrient that is digested is known as the "coefficient of digestibility." The coefficient of digestibility is obtained by dividing the amount of the nutrient digested by the total amount of the nutrient consumed, and multiplying the result by 100.

Determination of Coefficients of Digestibility. — The coefficients of digestibility of the different nutrients of many feeds have been determined by what are known as digestion

experiments. In a digestion experiment, the feedingstuff is first analyzed to determine the percentage of each nutrient present. The animal then is fed weighed quantities of the feedingstuff under experimentation for a period of one or two weeks, called the preliminary period, during which time the residues of previous feeding are excreted from the body.

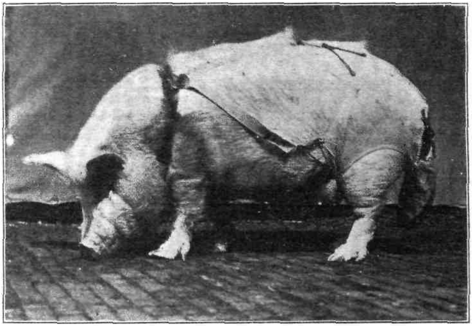

FIG. 12. — Digestion harness on a pig. (Illinois Experiment Station.)

The preliminary period is followed by a test period of one to three weeks in length. During the test period, the ration is weighed carefully, deducting the weight of any uneaten residue. The feces of the animal are collected usually in a rubber bag which fastens on to the hindquarters of the animal by a light harness. Figure 12 shows a digestion harness on a pig. Sometimes, especially in the cases of cattle and horses, they are collected with a shovel by attendants who watch the

animal day and night. Other times, especially in case of hogs, the animal is put into a stall or cage which has a floor made of coarse wire screening through which the feces drop on to a cloth stretched below. After collection, the feces are weighed and analyzed. Knowing the total amount of each nutrient which the animal consumes in a given time, and the amount of each nutrient which it excretes in the feces during the same time, it is an easy matter to calculate the amount of each nutrient digested, and the coefficient of digestibility of each nutrient of that particular feed. For example, during a seven-day digestion period, a hog consumed 49 pounds of corn which had the following chemical composition: dry substance, 86.38 per cent; crude protein, 9.80 per cent; nitrogen-free extract, 70.03 per cent; crude fiber, 1.91 per cent; and fat, 3.47 per cent. During this period, the animal excreted 12.6 pounds of feces, which had the following chemical composition: dry substance, 36.48 per cent; crude protein, 6.83 per cent; nitrogen-free extract, 16.72 per cent; crude fiber, 4.93 per cent; and fat, 4.65 per cent.

In order to find the coefficients of digestibility of the nutrients of the corn in this experiment, one first obtains the total amount of each nutrient consumed by the hog, by multiplying the amount of corn consumed, — 49.0 pounds, by the per cent of each nutrient in the corn, and then dividing the result by 100. Thus the total dry substance consumed was 49.0 times 86.38 divided by 100, or 42.33 pounds. The amounts of crude protein, nitrogen-free extract, crude fiber and fat consumed are obtained in similar manner.

The next step consists in determining the amount of each

nutrient excreted in the feces, by multiplying the weight of the feces by the per cent of each nutrient present in them, and then dividing the result by 100. Thus the amount of dry substance excreted in the feces was 12.6 times 36.48 divided by 100, or 4.6 pounds. *The total amount of each nutrient consumed, less the amount of that nutrient excreted in the feces, gives the amount of each nutrient digested.* Thus in the example the hog digested 42.33 minus 4.60 or 37.73 pounds of dry substance. *The amount of each nutrient digested, divided by the total amount of the corresponding nutrient consumed, and the result multiplied by 100, gives the coefficient of digestibility of each nutrient.* Thus the coefficient of digestibility of the dry substance in the above experiment was 37.73 times 100 divided by 42.33, or 89.13 per cent.

In the preceding example, the coefficients of digestibility are calculated as follows:

	Dry Substance	Crude Protein	N.-free Extract	Crude Fiber	Fat
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
49.0 lb. corn	42.33	4.80	34.31	0.94	1.70
12.6 lb. feces	4.60	0.86	2.11	0.62	0.59
Nutrients digested	37.73	3.94	32.20	0.32	1.11
Coefficient of digestibility, per cent	89.13	82.08	93.85	34.04	65.29

It should be noted, however, that coefficients of digestibility are not exact because, as has already been shown on page 47, the feces consist of dead and living bacteria, dead cells from the digestive tract, and the residues of the digestive juices, as well as undigested food residues. However, such

coefficients of digestibility are approximately correct, and they must be used until methods of separating the food residues from the other constituents of the feces are worked out.

There are many feeds which cannot be fed alone to certain classes of animals. For example, such feeds as corn and oats cannot be fed to cattle, sheep, and horses unless in combination with some roughage, as hay or straw, while such feeds as tankage and oil meal cannot be fed alone to hogs. Thus it is impossible to determine directly the coefficients of digestibility of many of the concentrates. In determining the digestibility of such a feedingstuff, it is fed with a feed whose coefficients of digestibility have been determined previously. The total consumption of each nutrient (*i.e.*, from the entire ration) and the total amount of each nutrient excreted in the feces is determined in the usual manner. The amount of each nutrient digested then is obtained by subtracting the amount of each nutrient excreted from the total amount of the corresponding nutrient consumed. The amount of digestible nutrients consumed from the feedingstuff whose digestibility is known is calculated by multiplying the amount of each nutrient consumed from that feedingstuff by its previously determined coefficient of digestibility, and dividing the result by 100. Subtracting these results from the total amount of each respective nutrient digested, the amount of each nutrient digested from the other feed is obtained. The coefficient of digestibility then is calculated as before.

For example, in a digestion period of seven days a hog was fed a ration consisting of ground corn and tankage, the coefficients of digestibility of the corn being determined in

a previous experiment. The chemical composition of the feeds used and the feces excreted was as follows:

	Dry Substance	Crude Protein	N.-free Extract	Crude Fiber	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Corn	86.38	9.80	70.03	1.91	3.47
Tankage	94.56	60.91	4.30	3.95	13.69
Feces	42.22	14.63	14.91	5.17	1.77

During the digestion period, the hog consumed 28 pounds of corn and 7 pounds of tankage and excreted 10.3 pounds of feces. Having these data, one calculates the amount of each nutrient digested as outlined on page 59.

	Dry Substance	Crude Protein	N.-free Extract	Crude Fiber	Fat
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
28 lb. corn . . .	24.19	2.74	19.61	0.53	0.97
7 lb. tankage . .	6.62	4.26	0.30	0.28	0.96
Total ration . .	30.81	7.00	19.91	0.81	1.93
10.3 lb. feces . .	4.35	1.51	1.54	0.53	0.18
Nutrients digested	26.46	5.49	18.37	0.28	1.75

Having determined the amount of each nutrient digested from the entire ration, the next step is to determine the amount of each nutrient digested from the corn. From a previous test period the coefficients of digestibility of corn were found to be as follows: dry substance, 88.2 per cent; crude protein, 78.8 per cent; nitrogen-free extract, 93.4 per cent; crude fiber, 30.0 per cent; and fat, 67.0 per cent. Thus, knowing the amount of each nutrient of the corn

consumed, and the percentage of it which is digestible, one obtains the amount of each digestible nutrient in the corn by multiplying the total amount of each nutrient of the corn by its coefficient of digestibility and dividing the result by 100. Obviously, subtracting the amount of digestible nutrients of the corn from the digestible nutrients of the total ration leaves the amount of nutrients digested from the tankage. Then dividing the amount of each nutrient digested from the tankage by the amount of the corresponding nutrient consumed from the tankage, and multiplying the result by 100 gives the coefficients of digestibility of the nutrients of the tankage.

Returning to the example cited, the coefficients of digestibility of tankage are calculated as follows:

	Dry Substance	Crude Protein	N.-free Extract	Crude Fiber	Fat
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Digested from total ration	26.46	5.49	18.37	0.28	1.75
Digested from corn	21.34	2.16	18.32	0.16	0.65
Digested from tankage	5.12	3.33	0.05	0.12	1.10
Coefficient of digestibility of tankage (per cent)	77.34	78.17	16.67	42.86	114.59

This indirect method of calculating the coefficients of digestibility is open to criticism because all of the difference between the values for the single feed and the corresponding values for the combined feeds is credited to the single feed, whereas it is probable that in the combined feeds each feed exerts an influence upon the digestibility of the other. Also

all the errors of the determination are thrown upon one feed. Consequently absurd results are often obtained, as in the case of the coefficient of digestibility of fat in the previous example. Thus at the Illinois Station,[1] Grindley, Carmichael, and Newlin fed four pigs a ration of middings alone; later a ration of corn and middlings in equal parts; and then a ration of corn alone. The coefficients of digestibility of corn and middlings as actually determined were materially different from the coefficients calculated indirectly by the method just described. Thus the average coefficients of middlings when determined directly and when determined indirectly when fed with corn, were as follows:

	Dry Substance	Crude Protein	N.-free Extract	Crude Fiber	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Alone	74.3	79.9	81.3	22.7	84.7
With corn . . .	70.2	77.5	77.2	0.2	89.3

This shows that the indirect method is not exact by any means. However, this is the only method of determining the coefficients of digestibility for each feed when more than one feed is used and, until a better one is formulated, it must be used.

Knowing the coefficients of digestibility of two feeds, a third may be added to the ration, and its digestibility calculated in a similar manner.

Digestibility of Mineral Matter. — Owing to the many errors involved in the determination, and the great variability of the results obtained, the coefficients of digestibility of min-

[1] Unpublished data.

eral matter are of little practical value, and hence they are not given often.

Digestibility of Crude Protein. — Protein from the concentrates is digested more thoroughly, as a rule, than protein from the roughages. This is probably due to the fact that the protein of the roughages is surrounded by tougher, more fibrous cell walls than the protein of the concentrates. Protein of the nitrogenous concentrates (*i.e.* concentrates containing a large amount of protein) such as the oil meals, legume seeds, distillers' grains, and gluten feed have the highest coefficients of digestibility, usually between 75 and 90 per cent. Proteins of the non-nitrogenous concentrates, as corn, oats, and wheat, are usually from 60 to 80 per cent digestible. Proteins of the concentrates which are relatively high in crude fiber, as corn-and-cob meal and the brans, have the lowest coefficients of digestibility among the concentrates, running sometimes as low as 50 per cent.

Of the roughages, the proteins of the leguminous hays, as alfalfa, clover, and cowpeas, have the highest coefficients of digestibility, — 60 to 75 per cent, being as high or higher than some of the concentrates. The proteins of the straws have the lowest coefficients of digestibility, — 23 to 33 per cent.

In general, the digestibility of crude protein seems to increase with the amount of protein in the feed and to decrease with the amount of crude fiber.

Digestibility of Nitrogen-free Extract. — Generally speaking, nitrogen-free extract is the most digestible nutrient, due to the fact that the starches and sugars are quite easily and quite thoroughly digested. As a rule, the nitrogen-free extract of the concentrates is more digestible than that of

the roughages. The digestibility of the nitrogen-free extract of the cereals and their by-products is especially high, — usually from 80 to 93 per cent, due to the large amount of starch which they contain.

The nitrogen-free extract of the roughages is less digestible, owing to the smaller amount of starch and larger quantity of less digestible carbohydrates, such as pentosans, which it contains. The coefficients of digestibility of the nitrogen-free extract of the roughages are usually from 40 to 70 per cent.

In general, the digestibility of nitrogen-free extract increases with the amount of starch which it contains, and decreases with the amount of crude fiber in the feed.

Digestibility of Crude Fiber. — The determination of the digestibility of crude fiber, owing to errors in the method of analysis, is only approximate at best. In many digestion experiments the digestibility of the nitrogen-free extract and crude fiber are not determined separately but are determined together as "carbohydrates."

Unlike the other nutrients, the crude fiber of the roughages is usually more digestible than the crude fiber of the concentrates. Thus the coefficients of digestibility of the concentrates are usually between 30 and 60 per cent, while those of the roughages are between 45 and 65 per cent. The crude fiber of corn fodder and the hays is usually more digestible than the crude fiber from the straws. This is due probably to the latter containing a larger amount of coarse, woody material. Also, the crude fiber of early cut hay is more digestible than that of late cut hay. Thus the crude fiber of timothy hay cut when in bloom had a coefficient of digestibility of 57 per cent while timothy hay cut after

the bloom had a coefficient of 43 per cent. In general, the older and tougher the plant the less digestible is the crude fiber.

Digestibility of Fat. — Owing to the inaccurate methods of analysis, the determinations of the digestibility of fat usually are less exact than those of any of the other nutrients excepting mineral matter.

The digestibility of the fat of the concentrates is greater than that of the roughages. Of the concentrates, the fats from packinghouse by-products, oil by-products, cereal by-products, and oil-bearing seeds have the highest coefficients of digestibility, in most cases being from 80 to 98 per cent. The fats of the other concentrates are usually from 65 to 90 per cent digestible.

In the roughages, the fats of corn fodder and stover have the highest coefficients of digestibility, — 67 to 74 per cent. The straws are lowest, — 30 to 39 per cent.

In general, the digestibility of fat increases with the amount of fat in the feed, and decreases with the amount of crude fiber.

FACTORS AFFECTING DIGESTIBILITY

There are certain factors which may affect the digestibility of feedingstuffs, either favorably or unfavorably. Also, there are certain factors which sometimes are said to affect the digestibility which, as a matter of fact, have no influence whatever. Obviously a knowledge of these factors and their influence, if any, upon the digestibility is of considerable practical importance.

Species of Animal. — The species of animal may have considerable influence upon the digestibility of a feeding-

stuff. As a rule, cattle digest the straws and coarse hays better than sheep, but with hays of good quality there is no difference. Cattle and sheep digest roughages more completely than does the horse, while the latter digests them much more thoroughly than the hog. The reason for this lies in the special provisions in the digestive tracts of ruminants and horses for the handling of roughage. On the other hand, the four classes of farm animals digest concentrates equally well.

Breed of Animal. — Different breeds of the same species of animal possess an equal digestive power. Thus Armsby and Fries [1] found that a pure-bred Angus steer and a scrub steer of predominant dairy type digested the same ration equally well.

Age of Animal. — Within reasonable limits the age of the animal does not influence the digestibility of the ration. Very young animals without teeth and very old animals with defective teeth of course would not be able to digest certain rations very thoroughly. Also until the rumen or paunch of the young ruminants is fully developed, the coarser part of the ration will not be digested thoroughly. Armsby and Fries [2] in experiments with two steers found but little difference in their digestibility as yearlings, as two-year-olds, and as three-year-olds.

The condition of the animal has no effect upon its power of digestion. In the experiment by Armsby and Fries, already quoted, it was found that a steer in good condition and one in poor condition digested the same ration equally well.

Work by the Animal. — It often has been assumed that a

[1] U. S. Dept. of Agr. Bureau of Amin. Indus. Bul. 128. [2] (*Ibid.*)

keen appetite, resulting from hard work, enables an animal to make greater use of the feed provided. Within reasonable limits, however, work has no effect upon the digestibility. However, it has been found that very hard work decreases the digestibility. Also it was found that horses working at a quick trot did not digest their rations as well as when working at a walk or when resting.

The individuality of the animal may have considerable effect upon the digestibility of the ration. In other words, animals kept under the same conditions and fed the same ration may have different powers of digestibility. Thus at the Illinois Experiment Station,[1] Grindley, Carmichael and Newlin conducted forty digestion experiments, each of ten days' duration, on four pigs. All conditions of the experiments were practically the same. The pigs were litter mates and had been fed together from birth. It was found that some of the coefficients of digestibility of certain pigs were uniformly higher than those of other pigs on the same ration. This difference sometimes amounted to as much as five per cent.

Palatability of the Ration. — Increased palatability of the ration probably has a slight beneficial effect upon the digestibility. The secretion of the digestive juices is partly under the control of the nervous system; thus, Pawlow, a great Russian physiologist, found that the smell or taste of food stimulates the nervous system and causes a flow of the digestive juices, which would tend to increase the thoroughness of digestion. The experienced feeder knows well the value of stimulating the appetites of his animals by means of attractive mixtures. Too much stress should not be placed upon

[1] Unpublished data.

the effect of palatability, however, as the increase in digestibility is probably small at best.

Cooking of Feeds. — Formerly, much labor and money was expended by farmers in steaming and cooking feeds. It has been found, however, that these processes do not *increase the digestibility, but, on the contrary, they usually* decrease it. Cooking decreases the digestibility of the protein especially. Potatoes and other starchy tubers are an exception to the rule, as their digestibility is increased by cooking. At the Oregon Experiment Station,[1] Withycombe and Bradley found that the steaming of vetch and of corn silage decreased considerably the digestibility of the ration.

Sweating and fermenting of feeds usually decrease the digestibility. On the other hand, the palatability of some feeds may be increased by such treatment and thereby make possible the consumption of material which otherwise would not be eaten at all. Thus while corn silage is not as thoroughly digested as corn fodder, it is more valuable as a feed because of its palatable and succulent nature. Brown hay shows an increased digestibility of crude fiber but decreased digestibility of protein and nitrogen-free extract.

Soaking of Feeds. — In the case of very hard, flinty corn, soaking for several hours previous to feeding may increase its digestibility, especially if the animals to which it is fed are old and have defective teeth.

Grinding of Feeds. — Grinding of the feed probably increases the digestibility to a certain extent. Jordan[2] states that in experiments with horses, grinding increased the digestibility of corn and oats 3 to 14 per cent, of corn alone

[1] Bul. 102. [2] "The Feeding of Animals," p. 133.

7 per cent, and of wheat 10 per cent. In a test with sheep unground oats were digested as completely as ground oats. On the other hand, Evvard,[1] at the Iowa Station, found that 60-pound pigs digested ear corn, shelled corn, and ground corn equally well. In case of 200-pound hogs there was a very slight difference in favor of grinding or grinding and soaking. In general, however, it is not advisable from an economic standpoint to grind corn and oats if the cost of grinding amounts to more than ten per cent of the value of the feed. In the case of fattening cattle which are followed by hogs, it is doubtful if it is ever profitable to grind the corn. Grain never should be ground for sheep except in the case of young lambs. In the case of animals with defective teeth, very young animals, horses at hard work, and dairy cows, it may be advantageous to grind the feed, providing the cost of grinding is not too great. Wheat, barley, rye, and emmer should be ground, crushed, or rolled for all animals except sheep.

Frequency of Feeding and Watering. — Within reasonable limits, the frequency of feeding has no effect upon digestibility. The same is true of the frequency of watering.

Patent Stock Foods. — The advertisements of most patent or proprietary stock foods "guarantee" that their use will cause the animal to digest considerably more of its ration and derive much more benefit therefrom. Inasmuch as patent stock foods usually consist of a mixture of common feedingstuffs, as bran, oil meal, ground oat hulls, and ground chaff, with a small quantity of salt and drugs, it is difficult to see how this can be so.

Michael and Kennedy, at the Iowa Experiment Station,[2]

[1] Unpublished data. [2] Bul. 113.

found that patent stock foods when fed with corn to hogs did not increase the digestibility of the ration. The hogs did not derive more benefit from their ration but, on the contrary, they required more feed to produce a pound of gain when stock foods were used than when corn was fed alone.

Snyder and Hummel, at the Minnesota Experiment Station,[1] in feeding a ration of corn and alfalfa hay to steers, found that the addition of a patent stock food materially decreased the digestibility of the dry matter, crude protein, crude fiber, and fat of the ration.

Patent stock foods, in some cases, may have a medicinal value but, if an animal needs medicine, usually it will be found to be better policy to call in a trained veterinarian.

Salt, although valuable and even necessary to the animal, does not increase the digestibility of the feed. In fact, large quantities of salt may decrease the digestibility by hindering the action of the digestive enzymes.

Stage of Growth of the Plant. — In general, as plants mature the relative proportion of crude fiber in the stems and leaves increases and the plant tissues become harder and tougher, and, consequently, the stems and leaves become less digestible. On the other hand, the proportion of nitrogen-free extract, *i.e.* the starches and sugars in the grain or seeds, increases, and hence the total amount of nutriment in the grain and seeds increases with approaching maturity. Thus, in order to get the greatest amount of nutrients, such plants as clover and timothy, which are grown primarily for the stems and leaves, should be harvested before the ripening of their seeds; while such plants as corn,

[1] Bul. 80.

oats, and wheat, which are grown primarily for their seeds, should be allowed to mature before harvesting.

Curing and Storage of Feeds. — The curing of feeds, if properly done, has no effect upon their digestibility. If improperly done, it may decrease the digestibility. Thus, exposure to rains leaches out a large part of the soluble and more digestible matter of the feed. Also, the digestibility of hay may be decreased by the loss of the leaves, which are the most digestible part of the roughages. Heating of hay in the mow or stack materially decreases the digestibility, as the more digestible portions of the plant are most subject to fermentation. The digestibility of hay may be decreased slightly by storage from one year to the next.

Amounts of Feed. — In recent investigations with cattle at the Illinois Experiment Station,[1] by Mumford, Grindley, Hall, Emmett, Joseph, and Allison, it was found that when a large proportion of concentrates to roughage was fed (5 parts of the former to 1 part of the latter), the amount of feed consumed had little or no influence upon the digestibility of the ration. However, when the proportion of concentrates in the ration was smaller (3 parts of concentrates to 1 part of roughage, and 1 part of concentrates to 1 part of roughage), the digestibility of the ration varied inversely with the amount of feed consumed. Maintenance rations were digested most thoroughly, with one-third feed, two-thirds feed, and full-feed rations ranking in the order named. Thus the coefficients of digestibility of the dry substance for the different lots were as follows:

[1] Bul. 172.

Ration	Maintenance Lot	One-third Feed Lot	Two-thirds Feed Lot	Full-feed Lot
Hay, 1 part; corn, 1 part	69.3	65.9	63.8	62.5
Hay, 1 part; corn, 3 parts	77.7	71.9	68.8	64.7
Hay, 1 part; corn, 5 parts	78.7	75.8	73.6	69.7
Hay, 1 part; corn, 4 parts; linseed meal, 1 part	79.6	76.9	75.04	76.0

These differences in the digestibility of the dry substance were due to differences in the digestibility of the carbohydrates. The protein and fat were digested equally well by the different lots.

Also, in experiments with cattle at the Möckern (Germany) Experiment Station, in experiments with cattle by Eckles at the Missouri Experiment Station,[1] and in experiments with sheep by Jordan and Jenter at the New York (Geneva) Experiment Station,[2] it was found that the digestibility decreased as the amount of the ration was increased.

Excess of Non-nitrogenous Nutrients. — If the ration contains an excess of carbohydrates in proportion to the amount of protein, the digestibility, especially of the protein, will be decreased considerably. Kellner[3] states that this depression is liable to occur in ruminants if the ration contains more than 8 to 10 parts of digestible carbohydrates and fats to each part of digestible protein. In case of pigs, he places the limit as 12 parts of digestible carbohydrates and fats to each part of digestible protein. If the proportion of carbohydrates and fats is in excess of these figures, he states that the ration will be less digestible.

[1] Research Bul. 4 and 7. [2] Bul. 141.
[3] "Scientific Feeding of Animals," p. 39.

Addition of Nitrogenous Nutrients. — The increase of the protein in a ration causes not only no depression of digestibility but, as just stated, it may increase the digestibility of the carbohydrates if there is an excess of them in the ration. Moreover, it seems from experiments at the Illinois Experiment Station that the addition of protein increases the digestibility of the entire ration. In an experiment by Mumford, Grindley, Hall, Emmett, Joseph, and Allison,[1] eight steers were fed a ration consisting of hay 1 part, and corn 5 parts. Then one part of the corn was removed and an equal amount of linseed meal (a feed containing about 34 per cent of protein) was substituted for it. The average coefficients of digestibility upon these two rations were as follows:

Ration	Dry Substance	Crude Protein	Carbohydrates	Fat
Hay, 1 part; corn, 5 parts	74.5	51.3	78.3	79.3
Hay, 1 part; corn, 4 parts; linseed meal, 1 part . .	76.9	67.7	79.9	83.5

The same thing, though in less degree, is indicated by experiments with hogs at the Illinois Station[2] by Dietrich and Grindley.

Digestible Nutrients in Feedingstuffs. — The practical stock feeder is not especially interested in the coefficients of digestibility of feedingstuffs nor in the chemical composition of feedingstuffs, provided he knows their content of *digestible nutrients.* Knowing the chemical composition of a feed and knowing its coefficients of digestibility, it is an easy matter to calculate the amounts of digestible nutrients in the feed.

[1] Ill. Agr. Exp. Sta. Bul. 172. [2] Bul. 170.

The percentage of each nutrient in the feed, multiplied by the corresponding coefficient of digestibility, and the result *divided by 100, gives the percentage of each digestible nutrient* in the feed. If the corn in the example cited on page 58 contained 9.80 per cent of crude protein, 82.08 per cent of which was digestible, the percentage of digestible crude protein in the corn would be 9.80 times 82.08 divided by 100, or 8.04. In other words, 100 pounds of the corn contained 8.04 pounds of digestible crude protein. The percentage of the other digestible nutrients of the corn may be obtained in similar manner. In the formation of rations, it is the percentage of digestible nutrients which are in the feeds, rather than the percentage of total nutrients which must be considered. The average content of digestible nutrients in feedingstuffs for horses, cattle, and sheep is given in Table 29, of the Appendix. Inasmuch as hogs do not digest their feeds the same as the other farm animals, Table 30, giving the average content of digestible nutrients in feedingstuffs for hogs, is given.

CHAPTER V

FUNCTIONS OF THE FEED NUTRIENTS IN THE ANIMAL BODY

In describing the digestion and absorption of the feed nutrients thus far, we have not found them to be of any nutritive value to the animal body. However, after digestion and absorption, the nutrients are ready for distribution by the blood for the utilization of the different tissues of the body for various purposes.

Metabolism. — The sum of all the changes which the absorbed food undergoes in the body is known as *metabolism.* The term metabolism includes all the changes and transformations which the digested nutrients undergo from the time they are absorbed until they are finally excreted from the body. It covers all the chemical changes in the animal body which constitute the life of the animal. Thus, the repair of body tissue, growth, the storage of fat, and the production of milk are all included in the processes of metabolism. On the other hand, the breaking down of the protein tissues and the oxidation of fat and carbohydrates for the liberation of their energy are also included in the metabolic processes. Thus the functions of the digested and absorbed nutrients of the feed are all included under the term, metabolism.

In general, animals use food in three ways: (1) for the formation, growth, and repair of the muscles, bones, ten-

dons, skin, hair, hoof, horn, and of the various organs, membranes, and secretions; (2) as fuel for the liberation of energy to produce work or heat; (3) for the formation of body fat; and (4) for the formation of body glycogen.

Functions of Water. — The importance of water to the animal organism is shown by the fact that ordinarily from one-third to two-thirds of the weight of the animal body consists of water. Water is necessary to the life of every cell. It acts as a solvent for various substances, it is a carrier of nourishment to the cells, and it removes waste products away from the cells. It often assists in cooling the body by evaporation from the skin as perspiration. It is necessary also for many important chemical reactions which take place in the animal body. Water ordinarily is excreted from the body, principally in the urine, and to a slight extent in the perspiration, feces, and water vapor from the lungs.

Functions of Mineral Matter. — It was noted under the discussion of the chemical composition of the animal body that from 3 to 6 per cent of the body is composed of mineral matter. The skeleton, especially, the protein tissues, the blood, and the body fluids all contain a certain amount of mineral matter.

Thus, the mineral matter of the feed is used for the formation and repair of the bones, the protein tissues, and the body fluids, such as the blood, the milk, and the digestive fluids. The mineral matter is also used to maintain the neutrality, alkalinity, or acidity, as the case may be, of the fluids and tissues of the body. It has no value for the production of fat or for the liberation of energy. Mineral matter is excreted from the body in the feces, urine, and, to a slight

extent, in the perspiration. In case of the herbivora, calcium and phosphorus are excreted almost entirely in the feces, while potassium is excreted in both the feces and urine. Mineral matter in the ration is absolutely necessary to the animal. Young animals fail to develop properly, or even may die if given an insufficient supply of mineral matter. If a mature animal is deprived of even common salt, it becomes weak, languid, and finally dies. When the

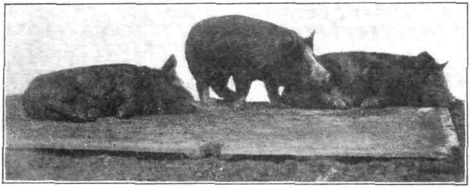

FIG. 13. — These pigs were fed a ration deficient in phosphorus. (Wisconsin Experiment Station.)

ration is deficient in mineral matter, the mineral matter of the bones is used to supply the deficiency for a time.

Ordinarily, the rations of our farm animals are not deficient in mineral matter, with the exception of salt, which usually must be added to all rations. The mineral matter in most feeds is sufficient, and those feeds which are low in mineral matter are fed usually in combination with other feeds which make up the deficiency. An exception to this statement is corn, a feed deficient in calcium, especially, and in phosphorus, to a certain extent, which often is fed to hogs without any supplement, or with supplementary

feeds which also are deficient in calcium, such as middlings, shorts, and red dog flour. Thus, when fed to immature pigs, corn should be supplemented by mineral matter in the form of rock phosphate, ashes, charcoal, salt, air-slacked lime, and bone meal, which may be kept in a trough or self-feeder where they are accessible to the pigs at all times. For

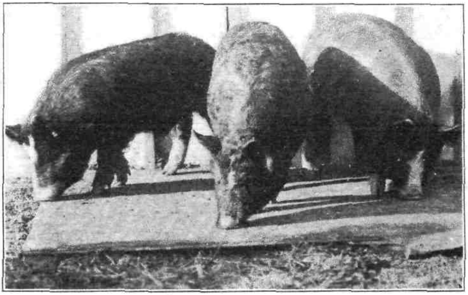

FIG. 14. — These pigs were fed the same ration as those in Figure 13, with the addition of phosphorus in the form of calcium phosphate. (Wisconsin Experiment Station.)

other reasons, which will be discussed later, corn should be fed to growing pigs in combination with such feeds as milk, tankage, or alfalfa, clover, or blue grass pasture. Figure 13 shows pigs whose rations were deficient in phosphorus. Figure 14 shows pigs fed the same ration as those in Figure 13, but with the addition of phosphorus in the form of calcium phosphate. Figure 15 shows bones from hogs which received a ration low in calcium. Apparently the bones

were broken and then healed again. Also the ration of growing colts fed on corn and timothy hay is liable to be deficient in calcium. Sometimes the ration of the dairy cow

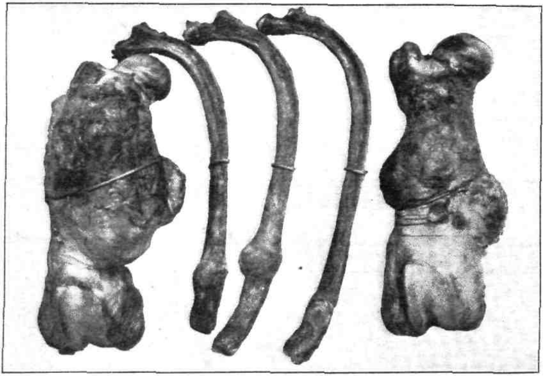

FIG. 15. — Abnormal bones from hogs whose rations were low in calcium (corn alone, and corn and soy beans). The bones seem to have been broken and to have healed again. (Ohio Experiment Station.)

is deficient in mineral matter, owing to the large amount of it required for milk production.

Functions of Crude Protein. — The functions of the proteins of the ration are as follows: (1) they serve as material for the repair and growth of the proteins of the tissues and fluids of the body, for fœtal development in the pregnant animal, and for milk production in the milk-producing animal; (2) they may serve as a source of energy;

(3) they may serve as a source of body fat; and (4) they may serve as a source of body glycogen.

The protein tissues of the body, especially the more active ones, are continually being broken down or worn out and must be repaired in order to maintain the life of the animal. It was stated that in digestion, the proteins are split up into the simple amino acids of which they are composed and are absorbed in this form. The absorbed amino acids are carried by the blood to the various protein tissues of the body, such as the muscular tissue, the connective tissue, etc. Inasmuch as all proteins are not composed of the same amino acids, each tissue probably selects from the blood only those amino acids which can be used for its repair.

It has already been shown that growth consists largely of an increase of the protein tissues of the body. Thus the tissues take up from the blood those amino acids which may be used for growth and build them up into the tissue proteins. Also they may be used for fœtal development or milk production. If there is any surplus of amino acids in the blood above the needs of the protein tissues for repair and growth, it may be oxidized for the liberation of energy. The principal end products of the oxidation of the amino acids are water, carbon dioxide, urea, ammonia, and uric acid. The carbon dioxide is excreted largely through the lungs, and the other products are excreted through the urine, mainly, and through the perspiration, to a slight extent.

Any surplus of amino acids above the demands of the body for repair and growth which is not used for fuel purposes probably may be converted into fat and glycogen and stored as such in the body, although this has never been proven

definitely. According to Kellner,[1] one hundred pounds of digestible protein in the feed above the requirements of the body for repair and growth produces 23.5 pounds of body fat.

As in the case of mineral matter, a certain amount of protein is absolutely essential not only for the satisfactory development of the animal but for life itself. An animal fed on a protein-free ration will soon starve to death, while an animal receiving an insufficient amount will not make a satisfactory development.

It has already been stated that certain amino acids are absolutely essential to life, while a certain amino acid is essential only to growth. Thus not only must the ration contain a sufficient amount of protein, but the protein must contain those amino acids which are essential for the maintenance and growth of the body tissues. It has already been shown that the proteins may differ greatly in their content of the different amino acids and, consequently, that they may differ in nutritive value. Thus, if a protein like zein of corn which is lacking in essential amino acids is fed, it cannot be used for repair or growth unless the missing amino acids are supplied in some other protein. In an experiment with a man,[2] it has been found that the following proteins ranked in the order named: meat, milk, rice, potato, bean, bread, and corn. In recent experiments by McCollum with pigs at the Wisconsin Station,[3] the following proteins ranked in the order named: skim milk, casein, corn, wheat, oats, linseed meal, wheat embryo. Thus, when feeds are used whose proteins contain

[1] "The Scientific Feeding of Animals," p. 64.
[2] Lusk, "Basis of Nutrition," p. 20.
[3] Jour. of Biol. Chem. XIX, 1914, p. 323.

only a small amount of certain of the essential amino acids, larger amounts of feed must be fed in order to supply these acids, or they must be added to the ration by the use of a supplementary feed which contains them.

Zein, the protein which makes up more than half the crude protein of corn, is entirely lacking in three amino acids, one of which is essential to life, and another of which is essential

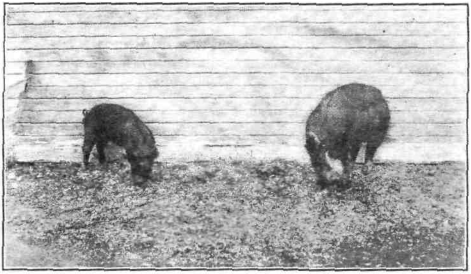

FIG. 16. — The ration of these pigs was deficient in the amount and quality of protein. Another pig of this lot died before this photograph was taken. The "runt" died the day after this photograph was taken. (Illinois Experiment Station.)

to growth. Thus corn, when fed alone, as is often done in case of hogs, does not furnish enough of these two essential amino acids to satisfactorily fulfill the requirements of the animal. In experiments at the Illinois Experiment Station,[1] by Emmett, Grindley, Joseph, and Williams, pigs fed corn, a small amount of blood-meal, and mineral matter were stunted in their growth, had weak, light bones, lost

[1] Bul. 168.

their appetites, became weak, languid, stiff in their hind quarters, and, in several cases, died. Figure 16 shows the low protein lot of pigs of this experiment. The smaller pig died the day after the photograph was taken and another pig of this lot died before the photograph was taken. On

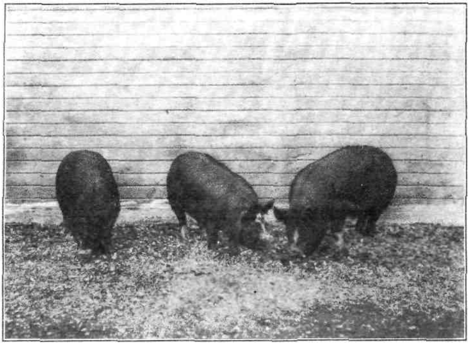

FIG. 17. — The ration of these pigs was the same as that of the pigs shown in Figure 16 with the addition of sufficient protein of the proper quality. (Illinois Experiment Station.)

the other hand, pigs fed a liberal amount of blood-meal in addition to corn and mineral matter made a normal growth. Figure 17 shows another lot of this experiment which received a sufficient amount of blood-meal to remedy the defects of the corn protein. Figure 18 shows cross-sections of some of the bones of a few of the pigs of this experiment. Note that the bones of the medium and high protein lots

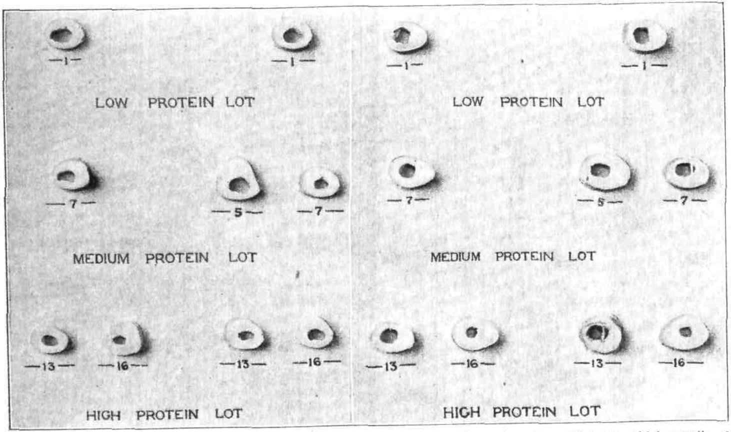

FIG. 18. — The effect of the amount and kind of protein upon the bones of growing pigs. Note the thicker walls of the bones of the medium and high protein pigs. (Illinois Experiment Station.)

have thicker walls than those of the low protein lot. Figure 19 shows a lot of pigs at the beginning of an experiment in which they were fed corn and mineral matter. Figure 20 shows the same pigs after 196 days on this ration. Thus, when fed to hogs, and especially to growing pigs, corn should be supplemented not only by mineral matter but also by

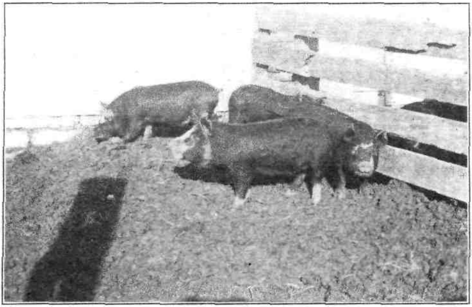

FIG. 19. — Pigs at the beginning of a 196-day feeding period upon corn alone. Average weight, 39 pounds. (Kentucky Experiment Station.)

some nitrogenous feed, as tankage, middlings, oil meal, clover or alfalfa pasture, which furnishes the essential amino acids in which corn is deficient. To the other classes of farm animals, corn often is fed with a nitrogenous roughage as clover or alfalfa hay which, to a large extent at least, may furnish the essential amino acids in which the corn is deficient. However, when corn is fed to growing animals with a non-nitrogenous roughage, such as corn silage or timothy

hay, it may be necessary to add a nitrogenous concentrate, as linseed oil meal or bran, to supply the deficient amino acids.

Wheat gliadin, the protein which makes up about half the crude protein of wheat, is deficient in lysine, an amino acid which is essential to growth. Thus in experiments by Hart and McCollum at the Wisconsin Station,[1] wheat and mineral matter did not produce maximum growth in pigs,

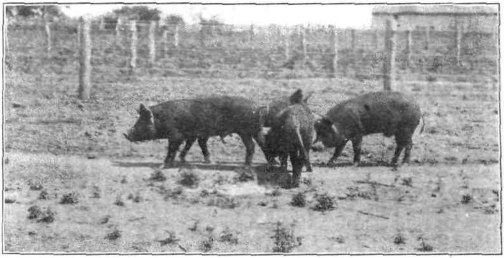

FIG. 20. — The same pigs as shown in Figure 19 after 196 days of feeding corn alone. Average weight, 64 pounds. (Kentucky Experiment Station.)

while the addition of a small amount of casein (which contains all the essential amino acids) caused normal growth. Gliadin from rye and the protein, hordein, from barley also will not produce maximum growth.

Functions of Carbohydrates. — The functions of the carbohydrates of the feed, *i.e.* the starches, sugars, celluloses, pentosans, etc., are as follows: (1) to serve as fuel for the liberation of energy; (2) to serve as a source of body fat; and (3) to serve as a source of glycogen in the animal body.

[1] *Jour. of Biol. Chem.* XIX, 1914, p. 373.

The carbohydrates in the ordinary ration of the corn-belt serve as the principal source of energy to the animal body. True, the protein and fat also may serve the same purpose but, as the former is more expensive and the latter not so plentiful, the carbohydrates usually furnish the larger part of the fuel for the animal body.

It was stated that the starches and sugars are absorbed in the form of glucose and other simple sugars very similar to glucose, and a small amount of organic acids. They are carried by the blood to the liver which acts as a storehouse and regulator to the supply of glucose in the blood. In the liver, glucose is changed to glycogen or animal starch and stored. Then as needed, the glycogen is reconverted to glucose, which passes again into the blood and is carried to the tissues, where it may be changed back into glycogen and temporarily stored before it is oxidized, or it may be oxidized directly with the liberation of energy and the formation of carbon dioxide, which is excreted through the lungs, and water, which is excreted mainly through the urine and to a slight extent through the lungs and perspiration. The crude fiber is absorbed in the form of salts of organic acids, which probably are oxidized in the tissues with the liberation of energy and the formation of carbon dioxide and water.

If there is any surplus of carbohydrates above the needs of the body for energy, it may be converted into fat and stored in the body. It was long contended that carbohydrates could not serve as a source of body fat, but it has been proven that they do have this function. In fact, the carbohydrates, owing to the high cost of protein and the scarcity of fat in ordinary rations, are the most important source of body fat in most feeding operations. This is true especially in the corn-belt.

The different kinds of carbohydrates have different values for fat production. Thus 100 pounds of digestible starch or crude fiber fed above the maintenance requirement of the animal may produce about 25 pounds of body fat, while the same amount of digestible cane sugar may produce only 19 pounds of fat. According to Kellner,[1] protein and carbohydrates have about the same values as fat producers.

Functions of Fat. — The functions of the fat of the feed are: (1) to serve as fuel for the liberation of energy; and (2) to serve as a source of the body fat.

The absorbed fat is carried by the blood to the muscular tissues, where it may be oxidized immediately for the liberation of energy. The end products of the oxidation are carbon dioxide and water. The carbon dioxide is excreted mainly through the lungs, and the water is excreted mainly through the urine.

Any excess of fat above the needs of the body for the production of energy may be stored in the cells of the tissues as body fat. The body fat acts as a reserve food supply which may be called upon to furnish energy to the animal body at any time when the ration is insufficient to supply its demands.

One hundred pounds of digestible fat in the ration above the requirements of the animal for maintenance may form from 47 to 60 pounds of body fat. In general, fat is about $2\frac{1}{4}$ times as valuable for the production of body fat as the same amount of protein or carbohydrates.

The Nutritive Ratio. — Inasmuch as it is very difficult to remember even approximately the relative amounts of digestible nutrients in the feedingstuffs, scientists have endeavored to simplify it by introducing the term, nutritive

[1] "The Scientific Feeding of Animals," p. 75.

ratio. The nutritive ratio, although it does not state the amounts of the different nutrients in a feedingstuff, does indicate the relative proportion of the nutrients present.

The nutritive ratio is the ratio of digestible nitrogenous nutrients to digestible non-nitrogenous nutrients in a feed or ration; *i.e.* it is the ratio of digestible crude protein to digestible carbohydrates and digestible fat. The nutritive ratio may be regarded as expressing the relative value of feeds as flesh-, and as fat-, or energy-formers. The nutritive ratio indicates at a glance whether a feedingstuff is suitable for growing, fattening, work, or milk-producing animals, or whether it should be used in combination with other feeds, in order to have the proper proportion of nutrients in the ration.

Inasmuch as fat is about $2\frac{1}{4}$ times as valuable for fat production as protein and carbohydrates and, as was stated on page 19, as fat contains about $2\frac{1}{4}$ times as much energy as the same amount of protein and carbohydrates, the amount of digestible fat is multiplied by $2\frac{1}{4}$ and added to the amount of digestible carbohydrates, and the sum is then divided by the amount of digestible protein. The first term of the ratio is always "1," while the second term is obtained by the following formula:

$$\frac{\text{digestible carbohydrates} + 2\frac{1}{4}\text{ (digestible fat)}}{\text{digestible protein}} = \text{2d term}$$

The nutritive ratio is written as "1 : 6" or "1 : 14," or whatever it may be. It is read as "one to six," or "one to fourteen." Thus one finds the nutritive ratio of corn as follows: 100 pounds of corn contain 7.8 pounds of digestible protein, 66.8 pounds of digestible carbohydrates, and 4.3 pounds of digestible fat. Then, substituting in the above formula:

$$\frac{66.8 + 2\frac{1}{4}(4.3)}{7.8} = 9.8$$

Therefore the nutritive ratio of corn is 1 : 9.8.

The nutritive ratio of a ration containing two or more feeds is obtained by calculating from Table 29 or 30 of the Appendix, the amount of digestible protein, digestible carbohydrates, and digestible fat in the ration and substituting these values in the above formula. Thus one calculates the nutritive ratio of a ration of 16 pounds of corn, 3 pounds of linseed oil meal, and 8 pounds of clover hay as follows:

	Digestible Protein	Digestible Carbohydrates	Digestible Fat
	Lb.	*Lb.*	*Lb.*
3 lb. oil meal . . .	0.91	0.96	0.21
16 lb. corn	1.25	10.69	0.69
8 lb. clover hay . .	0.57	3.02	0.14
Total ration . .	2.73	14.67	1.04

$$\frac{14.67 + 2\frac{1}{4}(1.04)}{2.73} = 6.2$$

Therefore the nutritive ratio of the ration is 1 : 6.2.

Ordinarily, a nutritive ratio of 1 : 6 or less is called a narrow ratio, *i.e.* the feedingstuff or ration contains a relatively large amount of protein and a relatively small amount of carbohydrates and fat. A ratio of 1 : 7 to 1 : 9 is called a medium ratio, *i.e.* there is present a medium amount of protein and a medium amount of carbohydrates and fat. A ratio of 1 : 10 or greater is called a wide ratio, *i.e.* the proportion of protein to carbohydrates and fats is relatively small. The nutritive ratios vary considerably for different feeds, *e.g.* from 1 : 0.1 in the case of dried blood to 1 : 57.9 in the case of rye straw.

CHAPTER VI

ENERGY IN FEEDINGSTUFFS AND ITS USES IN THE ANIMAL BODY

ENERGY is defined by the physicist as the capacity of performing work. Inasmuch as the muscular tissues of farm animals are always doing a certain amount of work, it is of interest to study the ways in which animals utilize energy and to study the values of the different nutrients and the different feedingstuffs as sources of energy.

There are two kinds of energy, kinetic and potential. Kinetic energy is energy due to motion; *e.g.* a moving train has energy due to its motion; heat is a form of energy due to the motion of the heat waves. In other words, kinetic is active energy. Potential energy is energy due to position or composition; *e.g.* a coiled watch spring has energy due to its position; starch has energy due to its composition. Potential energy is stored energy. These two forms of energy are interchangeable from one to the other. Thus the plant by means of its chlorophyll can take the kinetic energy or heat of the sun's rays and change it to the potential form, storing it in the form of proteins, carbohydrates, and fats. This potential energy may be changed back to kinetic form by burning the plant and liberating the stored energy in the kinetic form as heat. In similar manner, the animal can take the potential energy of its feed and

change it to kinetic form to warm the body, or to do work; or the animal can store a part of the potential energy of the feed in the animal body in the potential form as fat. The animal, however, is unable to utilize directly the kinetic energy of the sun's rays as does the plant, and, consequently *the animal kingdom is dependent for its supply upon the* potential or stored-up energy of the vegetable kingdom. Thus, besides *furnishing the proteins and mineral matter* necessary for the repair and growth of the animal, the feed *is the sole source of the energy so essential to all the phenomena of life.*

The units used for the measurement of energy are the *Calorie* and the *therm.* A Calorie is the amount of energy in the form of heat required to raise the temperature of one kilogram of water through one degree Centigrade, or of one pound of water through four degrees Fahrenheit. A therm is one thousand Calories. When speaking of the energy values of feedingstuffs, the therm is used more generally; while when speaking of the energy values of human foods, the Calorie is commonly used.

Gross Energy or Heat of Combustion. — The total amount of energy stored in a feedingstuff is called its gross energy or the heat of combustion. The gross energy of a feed is determined by burning it in an apparatus known as the *bomb calorimeter*, which consists essentially of a steel cylinder or bomb surrounded by a known quantity of water. A sample of the feedingstuff is placed in the bomb, which is then filled with oxygen to insure complete combustion. The sample is ignited by means of an electric current, and the amount of heat liberated in the combustion is determined from the rise in the temperature of the water surrounding

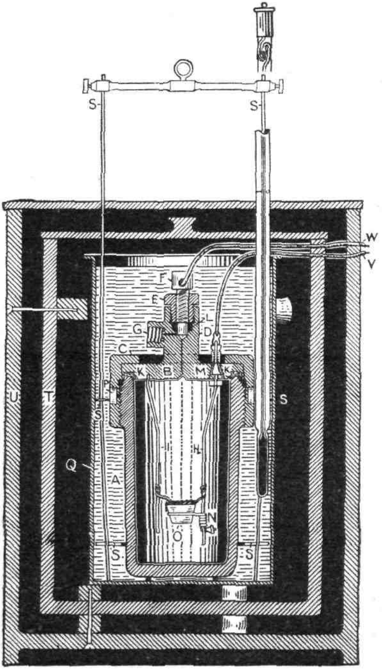

FIG. 21. — Section of a bomb calorimeter. (Storrs Experiment Station.) *U*, outer bucket; *T*, inner bucket; *Q*, metal pail; *A*, water; *S*, stirring apparatus; *B*, *M*, *K*, steel bomb, lined with platinum; *O*, platinum dish in which feed sample is placed; *G*, valve for letting in oxygen; *V*, *W*, *H*, *I*, electrical connections.

the bomb. Figure 21 shows a cross-section of a bomb calorimeter.

The gross energy of one pound of each nutrient is approximately as follows: protein, 2.6 therms; carbohydrates, 1.9 therms; and fat, 4.2 therms. The gross energy of the hays and straws is about 1.7 therms per pound, while that of the grains and other concentrates usually is from 1.7 to 2.0 therms per pound. A knowledge of the gross energy values of feedingstuffs, however, is of little practical value, as it rarely if ever happens that all of the energy stored up in the feed is available to the animal for its life processes.

Metabolizable or Available Energy. — Not all the energy of a feedingstuff is accessible to the animal body. Some of the energy of the feed passes through the body in unliberated form in the feces as the undigested food residue. Some of the energy passes out of the body unliberated in the form of combustible gases, as methane and hydrogen, which are formed during the fermentation of the feed in the rumen and large intestine. Further, some unliberated energy is lost by the excretion of only partially oxidized substances, as urea in the urine.

Thus one must differentiate between the amount of the gross energy of a feed and the amount of energy which actually is liberated or made available in the animal body. That part of the gross energy which may be liberated in or utilized by the animal in the processes of metabolism is called the *metabolizable energy* or *available energy* of the feed. Mathematically, the metabolizable energy of a feedingstuff may be regarded as the total energy of the feed less the energy of the feces, urine, and excreted gases.

The gross energy of a feed may be compared to the heat

of combustion of coal placed under the boilers of a steam engine. Thus one may compare the losses of energy in the animal body to the unburned or only partially burned soot, smoke, and cinders of the coal. The energy of the coal which actually is liberated under the boiler of the engine

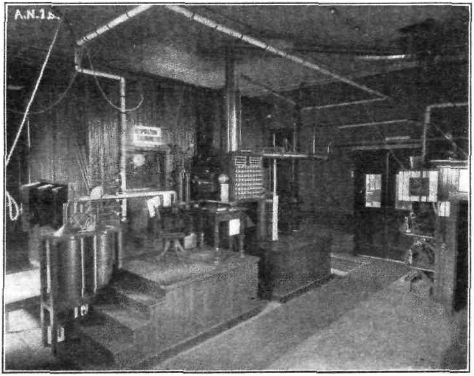

FIG. 22. — Respiration calorimeter at the Institute of Animal Nutrition, State College, Pa.

corresponds to the metabolizable or available energy of the feed.

The metabolizable energy of a feedingstuff is determined by means of the bomb calorimeter already mentioned, and an apparatus known as the *respiration calorimeter*. The respiration calorimeter is a very complicated apparatus, by means of which the amounts of gas, urine, feces, and heat

excreted by an animal can be measured. It consists of a closed chamber large enough to accommodate the animal under experimentation. Fresh air is pumped into the chamber and the vitiated air is pumped out and analyzed to determine the gases excreted by the animal. The feces are collected by means of a digestion harness, and the urine by means of a rubber funnel and duct strapped on to the belly of the animal. The heat given off by the animal is determined by the rise in temperature of a known amount of water which flows through radiators in the chamber and absorbs the heat given off by the animal. The only respiration calorimeter in this country large enough for experiments with cattle is that used by Armsby at the Institute of Animal Nutrition of the Pennsylvania State College.[1] Figure 22 shows this respiration calorimeter.

In determining the metabolizable energy of a feedingstuff, its gross energy is determined by the bomb calorimeter. A known amount of it is fed to an animal wearing a digestion harness and urine funnel in the respiration calorimeter. The feces, urine, and combustible gases are collected, and the energy lost through them is determined by means of the bomb calorimeter. The energy of the urine, feces, and gases subtracted from the gross energy of the feedingstuff gives the amount of the metabolizable energy in the feedingstuff.

Uses of the Metabolizable Energy. — The metabolizable energy of the ration serves for three general purposes in the animal body: (1) it supplies energy for carrying on the different forms of work of the animal body; (2) in certain

[1] For a detailed description of this respiration calorimeter, see Penn. Exp. Sta. Bul. 104.

special cases, it supplies energy in the form of heat to keep the body warm; and (3) if the supply is in excess of the demands of the body for the first and second purposes, a portion of it may be stored up as gain of body tissue, especially as fat, or it may be used for milk production.

The work of the animal body may be regarded as made up of the following forms: (1.) work of the vital processes, including circulation and respiration; (2) work of digestion and absorption, including mastication, swallowing, rumination, peristaltic movements, and the activity of the various digestive glands; and (3) work of the voluntary muscles, such as walking and pulling.

The following diagram modified from Armsby,[1] briefly summarizes the uses of the metabolizable energy of the feed:

Metabolizable energy
- Work
  - Of vital process
  - Of digestion and absorption
  - Of voluntary muscles
- *Heat production*
- Storage of energy

Work of the Vital Processes. — A certain amount of energy is in constant demand for the performance of the work of the vital organs, such as the heart and lungs. The amount of energy expended in this manner is not under control of the animal, as these organs cease their labors only at death. Thus, it is apparent that in the living animal there always is an expenditure of a certain amount of energy for carrying on the vital processes of the body. If there is not enough energy in the ration for this purpose the animal uses its body

[1] "Principles of Animal Nutrition," p. 339.

glycogen and fat to furnish energy for the deficiency. After the body fat is used up, the animal uses the protein tissues of the body as a source of energy for the running of the vital organs, and then soon dies of starvation.

Work of Digestion and Absorption. — The consumption of feed by an animal is always accompanied and followed by a large increase in the amount of energy expended. This increase was formerly thought to be due entirely to the energy expended in the work of mastication, swallowing, rumination, fermentation, peristalsis, secretion of the digestive juices, and the distribution of the absorbed nutrients. Hence, it was spoken of as the energy expended for the work of digestion. Later experiments with dogs, cats, and men, however, appear to have shown that the energy expended in the mechanical work of digestion is but a small part of the increased expenditure of energy due to the consumption of food. In case of the carnivora and man, the greater part of the increased expenditure of energy seems to be due to an effect which the absorbed nutrients, particularly the amino acids, have upon the metabolism of the cells, stimulating them to higher oxidation and consequent liberation of energy in the form of heat. Thus the term, "work of digestion," as applied to the increased expenditure of energy after food consumption, is not strictly true, but in lieu of a better term we shall continue to use it. In herbivora, and especially in ruminants, the expenditure of energy due to actual work of digestion is much greater than in carnivora, due to the large amount of energy expended in the work of mastication and rumination, and to the loss of energy as heat of fermentation. However, whether the increased expenditure of energy after food consumption is due to actual work of digestion or to

stimulation of the metabolism by the products of digestion, the fact remains that there is a considerable amount of energy wasted in the form of heat when an animal consumes a feed. Armsby found that in case of steers about one-fourth of the gross energy of the ration was liberated in the form of heat. This means that a certain amount of the metabolizable energy of the ration is wasted as far as having any value for maintenance of, or production by, the animal is concerned.

Net Energy. — The part of the metabolizable energy of a feed which remains after deducting the amount of energy expended in the so-called "work of digestion," is called its *net energy*. The net energy is the measure of the net advantage derived by the body from the feed. In other words, the net energy of a feedingstuff represents the amount of energy which it may contribute to the animal body for maintenance and for productive purposes. Mathematically, the net energy may be defined as the gross energy minus the losses of chemical energy in the excreta and the increased heat production consequent upon the consumption of the feed.

Returning again to the comparison of the animal body with the steam engine, we may assume that the engine is self-stoking. In that case, not all of the energy liberated under the boiler is available to the engine for the production of work. A certain amount of it must be expended for the operation of the self-stoking apparatus which puts the fuel under the boilers. This expenditure of energy corresponds to the expenditure in the animal body for the digestion, absorption, and distribution of the nutrients of the ration. The amount of the energy of the coal which remains after

making this deduction corresponds to the net energy of the feed.

The amount of net energy in a feedingstuff is obtained by determining by means of the respiration calorimeter the increased amount of energy expended by the animal after consuming the feedingstuffs, and subtracting this increase from the metabolizable energy. The result is the net energy. *Armsby has found that only 55 to 70 per cent of the metabolizable energy of the ration may be utilized for maintenance and for productive purposes.* As yet the net energy values of only 15 or 18 feeds have been actually determined, owing to the great expenditure of money, time, and labor necessary in their determination. However, Armsby and Fries [1] and Kellner [2] *have worked out a method by which the net* energy values of feedingstuffs may be calculated with some degree of accuracy. The net energy values of the common feedingstuffs as calculated by Armsby are given in Table 31, of the Appendix. These values are fairly accurate for these feeds when fed to cattle, sheep, and horses, but they have little value in case of hogs.

Net Energy Value of Nutrients. — In general, the average net energy values of the digested nutrients expressed in therms per pound are approximately as follows: protein, 1.02; carbohydrates, 1.00; and fat, 2.25. Thus for the production of energy, protein and carbohydrates have practically the same value, while fat is about $2\frac{1}{4}$ times as valuable.

Work of the Voluntary Muscles. — Any surplus of net energy above the maintenance requirement and, in special

[1] Penn. Exp. Sta. Bul. 71; Jour. Agr. Res., III, 6, p. 486.
[2] "Scientific Feeding of Animals," p. 82.

cases, the requirements for heat production, is available to the animal for the work of the voluntary muscles, such as walking, pulling, carrying, etc. However, not all the net energy available for the production of voluntary work can be recovered in the form of work. A certain amount is lost in the form of heat during the transformation. This loss may be compared to the loss of energy as heat occurring in any gas, gasoline, or other internal combustion engine. The gas is oxidized or exploded in the cylinders of the engine with the liberation of energy. In a comparable manner the digested and absorbed nutrients of the feed are oxidized in the cells of the muscular tissue of the animal with the liberation of energy. In either case, a considerable part of the energy liberated is not recovered as work but is lost in the form of heat. Anyone who has had experience with gas engines is familiar with the fact that only a fraction of the energy of the fuel can be recovered as work. A similar loss occurs in the cells of the muscles of the animal. When the nutrients are oxidized, a considerable amount of the energy (*i.e.* the net energy of the feed) is lost in the form of heat. Thus, on a cold day one walks faster, or slaps his arms, or stamps his feet, or shivers in order that the body may have the benefit of the heat which is generated in the performance of this work.

Coefficient of Utilization. — The percentage of the energy of the fuel which may be recovered by a motor in the form of work is known as the "coefficient of utilization." The coefficient of utilization with respect to the animal takes account only of the loss which occurs in the conversion of the net energy into work. That is, it is the percentage of the net energy of the ration (not the gross energy of the fuel

as in case of the engine), which may be recovered in the form of work. In experiments with men, it was found that 28 to 37 per cent of the net energy was recovered as work. Dogs recovered 29 to 31 per cent, and horses 29 to 38 per cent. In general, about one-third of the net energy may be recovered in the form of voluntary work, *i.e.* the coefficient of utilization is about 33 per cent. Computed on the basis of the gross energy of the ration, it is about 20 per cent. The best steam engines have about the same coefficient of utilization, while the average steam engine usually falls below 10 per cent. Good internal combustion engines range from 18 to 25 per cent.

Heat Production. — All warm blooded animals, such as man, the horse, cow, hog, etc., must maintain their body temperature at a practically constant level. If there is any considerable increase or decrease in the body temperature, the result is usually fatal to the animal. There is always a certain amount of heat generated in the living animal coming from the energy liberated in the work of the vital processes, the so-called work of digestion, and any voluntary muscular work done by the animal. Consequently a certain amount of heat is always being given off by the animal body by radiation and conduction. In mild weather the heat generated in the ordinary functions of the body is sufficient to maintain the body temperature. In fact, in warm weather, or when the amount of heat liberated is increased by excessive muscular work, the heat is generated by the body more rapidly than it can be disposed of by conduction and radiation. In such instances the body relieves itself of the surplus heat by the evaporation of water or perspiration from the surface of the body. In other words,

the animal sweats. If the heat is generated more rapidly than it can be removed by conduction, radiation, and perspiration combined, the body temperature rises and the animal suffers from sunstroke.

In cold weather, the animal looses heat by radiation and conduction much more rapidly than in warm weather. *Consequently, oftentimes the heat produced in the ordinary* processes of the body is not sufficient to maintain the temperature of the body and the animal must oxidize some of its body tissue or a part of its ration in order to provide heat to maintain the body temperature. If this does not suffice to maintain the body temperature, the animal freezes to death. Thus a man eats more in winter than in summer in order to provide extra fuel for keeping the body warm. The principle is the same as when one burns more coal in the *furnace on a cold day in order to keep up the temperature* of the house. Horses and hogs especially are susceptible to cold weather, and must use a part of their ration to keep them warm, unless properly protected. Cattle and sheep in ordinary winter weather do not do this, as the heat generated in the extensive fermentations in their digestive tract is sufficient usually to maintain their body temperature. If the weather is damp and windy, or if they are given very cold water to drink, it may be necessary even for them to burn feed to keep warm. Of course, energy expended in this way is a loss as far as economic production is concerned, and the feeder should avoid it, in so far as possible, by providing a comfortable shelter, by removing the chill from the drinking water, and by offering water several times daily in cold weather so that large amounts of cold water will not be taken into the body at any one time. A shelter

other than a dry, open shed is not necessary for beef cattle and sheep, except at calving or lambing time. Horses and hogs should have a fairly warm, comfortable enclosure.

Storage of Energy. — The animal body differs from the machine in that any energy above the amount required for the different forms of work and for heat production is not wasted, but it may be stored in the body, principally as fat, or as protein tissue, and used for the production of work or heat at any subsequent time when the energy of the ration is insufficient, or it may be used for the production of milk. It should be noted, however, that all other demands of the body for energy, including maintenance, heat production, and voluntary work, must be satisfied before there can be any storage of energy or any energy available for milk production.

Energy Values of Feedingstuffs. — From the standpoint of practical stockfeeding, it is the net energy contained in a feed which is of interest. Hence, in speaking of the energy values of feedingstuffs, one usually refers to the net energy values. Armsby's table showing the amounts of net energy contained in the more common feedingstuffs is given in Table 31, of the Appendix.

In general, feedingstuffs may be divided into two main groups according to the amounts of net energy contained in them. These two groups are (1) concentrates, and (2) roughages.

Concentrates may be defined as feedingstuffs which contain a relatively large amount of net energy (or digestible nutrients) in a small bulk. Ordinarily, concentrates have a net energy value of 60 therms or more per 100 pounds of feed. As might be expected from their definition, they

usually are highly nutritious in nature. Examples of common concentrates are corn, oats, the oil meals, middlings, and tankage.

Concentrates often are divided into "nitrogenous" and "non-nitrogenous" concentrates upon the basis of their protein content. Nitrogenous concentrates are high in digestible protein. They usually contain 11 per cent or more of digestible protein. Examples are tankage, the oil meals, and middlings. Non-nitrogenous concentrates are low in digestible protein and high in digestible carbohydrates and fats. They are often spoken of as *carbonaceous* concentrates. They usually contain less than 11 per cent of digestible protein. Examples are corn, oats, and barley.

Roughages may be defined as feedingstuffs which contain a relatively small amount of net energy (or digestible nutrients) in a large bulk. They contain a large percentage of crude fiber. Roughages usually contain less than 40 therms of net energy per 100 pounds, although there are a few exceptions. Nitrogenous roughages are relatively high in digestible protein. They usually contain 6 per cent or more of digestible protein. Examples are clover, alfalfa, and soy-bean hay. Non-nitrogenous roughages are relatively low in digestible protein. They usually contain less than 6 per cent of digestible protein. Examples are timothy hay, corn stover, and oat straw.

CHAPTER VII

THE COMPOUNDING OF RATIONS

Most of us will agree that the rations of our farm animals should be regulated, both in character and in quantity. This is necessary both from the standpoint of the physical well-being of the animal and from the financial well-being of the farmer. The appetite of the animal cannot be accepted as an accurate or practicable index of its feed requirements. If the farm animal, with the possible exception of the hog, is given free access to a number of different feedingstuffs and allowed to formulate its own ration, the result oftentimes will not only be disastrous from the financial standpoint, but, in many cases, it will mean permanent injury or even death to the animal. Thus the careful feeder always selects the feeds and usually regulates the amounts eaten.

Before taking up in detail the specific feed requirements of farm animals in terms of digestible nutrients and net energy, it may be well to mention some of the general guides that are followed more or less closely by practical feeders. A man cannot be a successful feeder unless he is thoroughly familiar with the practical as well as the scientific side of feeding. Of course, the only way to acquire a thorough knowledge of the practical side of stockfeeding is by actual experience, but in lieu of this experience, a knowledge of

some of the general practices followed by feeders will be of some value.

The ration should be so formulated as to satisfy the *appetite without exceeding the requirements of the animal.* It is obvious that unless the ration satisfies the appetite of the animal, the results will not be satisfactory, as the animal will be nervous and discontented. However, if the appetite is *satisfied only by feeding more than the requirements* of the animal, it will not only be uneconomical from a financial standpoint, but it may injure the animal. Both these conditions may be satisfied approximately by feeding the required amount of digestible nutrients in such bulk that the animal is " filled up " and the appetite is satisfied. In other words, it is accomplished by feeding a proper amount and proportion of concentrates and roughages. In many cases, in actual practice the ration is regulated by limiting only the concentrates and feeding the roughage *ad libitum*. For example, one usually limits the amount of corn which a hog eats while on pasture to that amount which, together with the pasture, will produce satisfactory gains. Then, if the hog is still hungry, he can eat the cheap roughage with safety until his appetite is satisfied. Although not always to be recommended, this method of regulating rations is often used. In feeding a very palatable roughage, as alfalfa hay or corn silage, it often is advisable to limit the amount of roughage fed in order to induce the animal to eat enough concentrates.

Also it is usually desirable to feed several feeds rather than one or two, not only for the sake of variety in the ration but also because in feeding only one or two feeds some of the essential amino acids may not be supplied in sufficient amounts for the best results.

Customary Rations for Farm Animals. — The following general rules will serve to give the inexperienced feeder a general idea of the nature and amount of the rations given to farm animals. It should be borne in mind that these rules should serve only as very general guides, to be modified to suit individual animals and different conditions with respect to the supply and relative costs of feeds.

HORSES

1. In general, feed 2 pounds of feed per day per 100 pounds live weight.

2. For a foal at weaning time, feed 2 quarts (2 pounds) of oats per day and hay *ad libitum*.

3. For a colt one year old, weighing about 700 pounds, feed 1 gallon (4 pounds) of oats per day and hay *ad libitum*.

4. For a horse which is doing no work, feed hay *ad libitum* and as much concentrates as necessary to keep the animal in good condition.

5. For a driving horse weighing about 1200 pounds, feed one pound of concentrates and one pound of roughage per day per 100 pounds live weight; or feed 3 gallons (12 pounds) of oats daily with hay *ad libitum*.

6. For a horse weighing about 1400 pounds, doing average farm work, feed $1\frac{1}{5}$ pounds of concentrates and 1 to $1\frac{1}{4}$ pounds of hay per day per 100 pounds live weight; or feed 24 ears of corn (17 pounds), or $1\frac{1}{2}$ gallons of oats (6 pounds) and 15 ears of corn ($10\frac{1}{2}$ pounds), or 3 gallons of oats (12 pounds) and 7 ears of corn (5 pounds) per day with hay *ad libitum*.

7. For a horse weighing about 1500 pounds at hard farm

work, feed $1\frac{1}{3}$ pounds of concentrates and 1 to $1\frac{1}{4}$ pounds of hay per day per 100 pounds live weight; or feed 30 ears of corn (21 pounds), or 20 ears of corn (14 pounds) and $1\frac{1}{2}$ gallons of oats (6 pounds) per day with hay *ad libitum*.

DAIRY CATTLE

1. For young calves (weighing about 100 pounds), feed 6 quarts of whole milk per day with clover or alfalfa hay *ad libitum*.

2. For calves (weighing about 300 pounds), feed 8 quarts of skim milk and 3 pounds of concentrates per day and clover or alfalfa hay *ad libitum*.

3. For the maintenance of dry cows, feed 20 pounds of corn silage and other roughage *ad libitum*, or 4 pounds of grain and roughage *ad libitum*, or run on pasture.

4. The average cow requires about 24 pounds of digestible dry substance daily. About two-thirds or 16 pounds of the digestible dry substance of the ration should be in the form of roughage and one-third or 8 pounds in the form of concentrates.

5. Feed about 2 pounds of dry roughage,[1] or 1 pound of dry roughage and 3 pounds of silage per 100 pounds of live weight together with concentrates as prescribed in Rules 6 and 7.

6. Feed one pound of concentrates [2] daily per every three pounds of milk produced daily and roughage *ad libitum*.

[1] When feeding silage due allowance should be made for the fact that it contains only about 25 per cent of dry substance. Thus 40 pounds of silage actually contain only about 10 pounds of dry substance.

[2] In feeding corn silage allowance should be made for the fact that it contains about 14 per cent of corn. For example, 40 pounds of silage would contain 5.6 pounds of corn.

7. Feed one pound of concentrates daily for every pound of butter fat produced per week and roughage *ad libitum.*

8. Use a variety of feeds for best results.

BEEF CATTLE

1. In general, feed $2\frac{1}{2}$ pounds of feed per 100 pounds live weight.

2. For maintenance, feed roughage *ad libitum.*

3. For wintering stockers, feed roughage *ad libitum.*

4. In getting fattening cattle on full feed, start them out with 2 pounds of concentrates per day per head and roughage *ad libitum.* Increase the concentrates one pound daily until they receive 10 pounds of concentrates per head, then increase the concentrates one pound every three days until they are on full-feed.

5. For fattening cattle on full-feed, feed $1\frac{3}{4}$ to 2 pounds of concentrates[1] and $\frac{3}{4}$ pound of roughage per day per 100 pounds live weight.

HOGS

1. In general, feed 3 to 5 pounds of concentrates per 100 pounds live weight according to age, giving larger rations to younger and smaller rations to older hogs.

2. For pigs at weaning time (weighing about 50 pounds), feed 5 pounds of concentrates per 100 pounds live weight, or 4 pounds of concentrates per day per 100 pounds live weight and forage *ad libitum.*

[1] In this connection it should be noted that many cattle feeders, especially outside the corn-belt, use much less concentrates and more roughage than prescribed by this rule. Haecker of the Minnesota Station recommends not more than 1 pound of grain per 100 pounds live weight.

3. For shoats (weighing about 100 pounds), feed 4 to 5 pounds of concentrates, or 3 to 4 pounds of concentrates per day and forage *ad libitum*.

4. For fattening hogs (weighing 200 to 300 pounds), feed 3 pounds of concentrates daily per 100 pounds live weight.

SHEEP

1. For young lambs (weighing 30 to 50 pounds), feed $\frac{1}{5}$ to $\frac{1}{2}$ pound of concentrates per day with roughage *ad libitum*.

2. For fattening lambs (weighing about 50 pounds), on full-feed, feed 1 pound of concentrates and $1\frac{1}{2}$ pounds of roughage per day.

3. For fattening sheep (weighing about 100 pounds), feed $1\frac{1}{2}$ pounds of concentrates and 1 pound of roughage per day.

4. For pregnant ewes (weighing about 150 pounds), feed roughage *ad libitum* until within a few weeks of lambing, then feed $\frac{1}{2}$ to 1 pound of concentrates per day.

5. For ewes with suckling lambs, feed $1\frac{1}{2}$ pounds of concentrates per day and roughage *ad libitum*.

Determining the Amount of Feed. — Accurate feeding usually requires either the actual weight or a careful estimate of the weight of the ration in order to adapt the amount of digestible nutrients or net energy to the actual requirements of the animals fed.

In feeding large lots of animals, as in the case of fattening cattle, hogs, and sheep, the concentrates, at least, may be easily weighed by the wagon-load, or the weight may be estimated approximately by weighing a standard measure of them, such as a bushel basket. The amount of roughage

usually may be estimated approximately, especially after one has had some practice. In feeding animals individually, as in the case of horses and dairy cows, the weight of the concentrates usually can be closely approximated by measuring the amounts fed. In case of a mixture of two or more concentrates being fed, definite quantities of each may be weighed and mixed in such quantity as to last for some time. Then the weight of a standard measure (*e.g.* one quart) may be obtained, and the amount given to each animal estimated accordingly. It is seldom practicable or necessary to weigh individual rations on the farm. However, it is well to check up the amount being fed by occasionally weighing the ration.

Estimating Weights of Concentrates. — Table 8 shows the weight of one quart, and the measure of one pound of the different concentrates.

Other rules for the estimation of the amount of grain are as follows:

1. One vertical inch wagon-box measure is equivalent to a little more than one bushel of ear corn.

2. One vertical inch wagon-box measure is equivalent to a little more than two bushels of shelled corn, oats, wheat, rye, or barley.

3. One hundred ears of corn are equivalent approximately to 70 pounds or one bushel.

4. Two and one-fourth cubic feet in the crib are equivalent to one bushel of well-dried ear corn, or two and one-half cubic feet in the crib are equivalent to one bushel of sappy ear corn.

5. One and one-fourth cubic feet in the crib are equivalent to one bushel of shelled corn or other grain.

TABLE 8. — AVERAGE WEIGHTS OF CONCENTRATES

FEEDINGSTUFF	ONE QT. WEIGHS	ONE LB. MEASURES
	Lb.	*Qt.*
Alfalfa meal	0.6	1.7
Beet pulp, dried	0.6	1.7
Buckwheat middlings	1.3	0.8
Barley, whole	1.5	0.7
Barley meal	1.1	0.9
Brewers' dried grains	0.6	1.7
Coconut meal	1.5	0.7
Cowpeas	1.7	0.6
Corn, whole	1.7	0.6
Corn, meal	1.5	0.7
Corn, bran	0.5	2.0
Corn and cob meal	1.4	0.7
Corn and oat feed	0.7	1.4
Cottonseed meal	1.5	0.7
Distillers' dried grains	0.6	1.2
Gluten meal	1.7	0.6
Gluten feed	1.3	0.8
Germ meal	1.4	0.7
Hominy meal	1.1	0.9
Linseed meal, old process	1.1	0.9
Linseed meal, new process	0.9	1.1
Malt sprouts	0.6	1.7
Molasses	3.0	0.3
Oats, whole	1.0	1.0
Oats, ground	0.7	1.4
Rye, whole	1.7	0.6
Rye meal	1.5	0.7
Rye bran	0.6	1.8
Rye middlings	1.6	0.6
Rice polish	1.2	0.8
Soy beans	1.8	0.6
Skim milk	2.0	0.5
Wheat, whole	2.0	0.5
Wheat, ground	1.7	0.5
Wheat bran	0.5	2.0
Wheat middlings (standard)	0.8	1.3
Wheat middlings (flour)	1.2	0.8

Estimating Weights of Roughages. — Although, as previously stated, it may not be advisable in all cases to regulate the amount of roughage, yet in many cases one needs to know approximately how much roughage will be consumed and how much roughage one has in order to estimate how many animals may be fed from the roughage on the farm.

The weights of loose hay, straw, corn fodder, or stover are quite difficult to estimate with any degree of accuracy, although after a little practice one may estimate approximately the weights of small amounts.

Woll[1] presents the following weights of different sizes of hay bales:

	Dimensions, inches	Weight, lb.
Small bales	$14 \times 18 \times 38$ / $16 \times 18 \times 36$	70 to 100
Medium bales	$17 \times 22 \times 36$ / $18 \times 22 \times 36$	100 to 150
Large bales	$22 \times 28 \times 46$	150 to 225

Ordinarily, timothy weighs a little heavier than clover or alfalfa.

The weight of hay in the mow may be estimated approximately, especially if the mow is regular in shape so that the cubic content may be obtained. There are approximately 590 cubic feet in a ton of hay when it has settled less than 60 days. After the hay is well settled, there are approximately 512 cubic feet in a ton. In Wyoming and Idaho, well settled alfalfa is figured at 512 cubic feet to the ton, and timothy and clover at 450 cubic feet to the ton.

There are several rules for estimating the amount of hay in stacks or ricks of more or less irregular shape. The first

[1] "Productive Feeding of Farm Animals," p. 103.

and most difficult step is to determine the content of the stack in cubic feet, and the second step is to divide the cubic feet in the stack by the number of cubic feet in a ton.

The United States Department of Agriculture[1] proposes the following rule for estimating the number of cubic feet in a stack:

$$V = FOWL$$

where:

V = volume in cubic feet.
O = distance in feet over the stack from the ground on one side to the ground on the other side at a point directly opposite.
W = width in feet of the stack at the ground.
L = length in feet of the stack at the ground.
F = a fraction varying from 0.25 to 0.37, depending upon the shape of the stack. If the stack is low and nearly triangular, 0.25 should be used; if it is tall, with very full sides, 0.37 should be used. Any number in between these two may be selected which seems to more nearly conform with the shape of the stack.

Of course, the accuracy of this method depends upon the ability of the operator to select the proper value for "F." Figure 23 shows cross sections of stacks of different shapes and corresponding values of "F."

In Wyoming and Idaho, the following formula for finding the cubic content of haystacks is legal:

$$V = \frac{O - W}{2} WL$$

where:

V = volume in cubic feet.
O = distance over the stack in feet.
W = width of the stack in feet.
L = length of the stack in feet.

[1] Cir. 131, Bureau of Plant Industry.

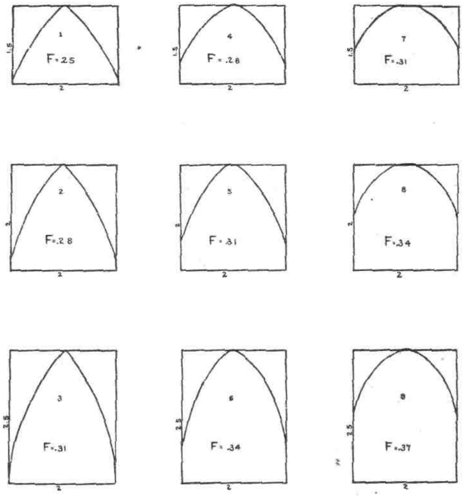

FIG. 23. — Cross sections of haystacks of different shapes showing the corresponding values for "F." (U. S. Department of Agriculture.)

In New Mexico the following formula is used:

$$V = \frac{OWL}{4}$$

where:

V = volume in cubic feet.
O = distance over the stack in feet.
W = width of the stack in feet.
L = length of the stack in feet.

Table 9, compiled from results published by the Iowa,[1] Nebraska,[2] Missouri,[3] and Wisconsin [4] Experiment Stations, shows the approximate capacities of silos of various sizes.

TABLE 9. — CAPACITY OF ROUND SILOS

Depth of silage in feet	Inside diameter of silo, in feet — Expressed in tons: 10	12	14	16	18	20	22	24	26
20	26	38	51	67	85	105	127	151	177
23	32	45	60	82	103	128	154	184	216
25	36	52	68	96	122	136	173	206	242
28	40	61	81	108	137	160	205	245	285
30	44	68	90	115	150	180	226	270	315
32	50	72	95	126	162	200	248	295	346
34	53	77	108	142	171	223	269	313	—
36	57	82	114	158	194	230	290	341	—
38	65	94	128	167	212	261	—	—	—
40	70	101	138	180	229	281	—	—	—
42	—	—	172	208	246	300	—	—	—
44	—	—	—	—	264	320	—	—	—
46	—	—	—	—	282	340	—	—	—
48	—	—	—	—	299	361	—	—	—
50	—	—	—	—	—	382	—	—	—

One bushel of silage weighs about 40 pounds.

[1] Bul. 141. [2] Bul. 138. [3] Bul. 103. [4] Bul. 214.

CHAPTER VIII

THE FEED REQUIREMENTS OF FARM ANIMALS

The Balanced Ration. — A balanced ration is a ration which contains all the nutrients in such proportions, forms, and amounts as will nourish properly, and without excess of any nutrient, a given animal for one day. The proportion refers to the proportion of digestible protein to the digestible carbohydrates and fat, as indicated by the nutritive ratio. The form refers to the character or bulk of the ration as indicated by the amount of dry substance. Extended study of the amount of each nutrient required by the different farm animals for the various purposes for which they are kept has led to the formation of so-called "feeding standards."

Feeding Standards. — Theoretically, feeding standards may be looked upon as formulas which tell at a glance the amount of each nutrient necessary to produce a given result. In practice, however, feeding standards cannot be regarded as such. In the first place, the requirements of farm animals for different purposes have not been determined accurately in many cases. In the second place, the requirements of animals of the same species are not constant, but are influenced considerably by such factors as the individuality, previous feeding, and temperament of the animal, temperature and other weather conditions, etc. Thus, no two animals have exactly the same requirement,

and they may vary considerably. If an animal is fed a light ration for a considerable period of time, it is probable that its requirements are lessened. It is a matter of common observation that a quiet, lazy animal requires less feed than a nervous, energetic one, and that animals do better in certain kinds of weather than in other kinds. In the third place, there are characteristics of feeds other than their chemical composition and energy values which must be considered in formulating rations. Theoretically, one might satisfy the requirements of a feeding standard by using feeds which in actual practice would not give satisfactory results. In the fourth place, individual feeds often vary considerably from the average chemical composition and energy value as given for that feed in the generally accepted tables. Consequently, then, one must not look upon the feeding standard as a hard and fast rule to be followed at all times, but only as a guide to be adapted to varying conditions and to be used in connection with one's practical knowledge of the amounts, proportions, and combinations of feeds which are used in stockfeeding. Although a knowledge of feeding standards is not essential to being a successful feeder of live stock, yet such a knowledge enables the inexperienced stockfeeder to learn the art more quickly, at less expense, and more thoroughly than when he depends upon experience as his only teacher. There have been a large number of feeding standards proposed, all of them having more or less value. The most important of these will be taken up and discussed.

The Wolff-Lehmann Standard. — Probably the best known and most widely used standards, at least until recently, are the Wolff-Lehmann standards given in Table

32 of the Appendix. These standards cover the requirements of practically all classes of farm animals under different conditions. They were presented first by Wolff, a noted German student of animal nutrition, in 1864. In 1896, they were revised by Lehmann, and since have been called the Wolff-Lehmann standards, or sometimes the "German standards." The latter term, however, is somewhat misleading as other standards also have been presented by German investigators in animal nutrition.

The Wolff-Lehmann standards attempt to show the requirements of farm animals under different conditions expressed in pounds of total dry substance, digestible crude protein, digestible carbohydrates, and digestible fat per *1000 pounds live weight. The nutritive ratio required* by the animal is given also.

The formulation of a ration, according to any feeding standard, consists essentially of three steps. (1) Having given the requirements for an animal of a given weight, usually 1000 pounds, the requirements of the animal under consideration are determined. (2) A "trial ration" is assumed, using the amounts and proportions of concentrates and roughages which, in the opinion of the feeder, are satisfactory. (3) The trial ration is modified by adding or deducting concentrates or roughages of such composition as to furnish approximately the required amounts of dry substance, digestible protein, digestible carbohydrates, digestible fat, and net energy, and the proper nutritive ratio.

Thus, for example, one calculates a ration according to the Wolff-Lehmann standard for a 1200-pound horse at light work as follows: According to the standard (Table 32, Appendix), the requirements of a 1000-pound horse at light

work are as follows: dry substance, 20 pounds; digestible protein, 1.5 pounds; digestible carbohydrates, 9.5 pounds; and digestible fat, 0.4 pounds. The ration should have a nutritive ratio of 1 : 7.0. The first step is to calculate the requirements of a 1200-pound horse, which are found to be as follows: dry substance, 24 pounds; digestible protein, 1.8 pounds; digestible carbohydrates, 11.4 pounds; and digestible fat, 0.5 pound. The second step is to assume a trial ration which will meet approximately the requirements as determined in the first step. From the amount of dry substance required and from practical experience (see rule 5, page 109), one judges that a ration consisting of 12 pounds of oats and 14 pounds of timothy hay will not be far amiss. Calculating the dry substance and digestible nutrients of this ration from Table 29 of the Appendix, the following results are obtained:

	Dry Substance	Digestible Protein	Digestible Carbohydrates	Digestible Fat
	Lb.	*Lb.*	*Lb.*	*Lb.*
Oats, 12 lb. . . .	10.8	1.1	5.9	0.5
Hay, 14 lb. . . .	12.2	0.4	5.9	0.2
Total ration . .	23.0	1.5	11.8	0.7

Comparing the nutrients of the trial ration with the requirements of the standard, it is seen that the trial ration is a little below the standard in dry substance and protein, and a little above it in carbohydrates and fat. Thus the third step is to modify the trial ration so that its nutrients conform to the standard. Consequently, a feed which is high in protein and low in carbohydrates should be sub-

stituted for part of the ration. Inasmuch as it is not desirable to lessen the bulk of the ration, one may substitute two pounds of linseed meal for two pounds of the oats of the ration. The ration then contains the following nutrients:

	Dry Substance	Digestible Protein	Digestible Carbohydrates	Digestible Fat
	Lb.	*Lb.*	*Lb.*	*Lb.*
Oats, 10 lb.	9.0	0.9	4.9	0.4
Linseed meal 2 lb.	1.8	0.6	0.6	0.1
Timothy hay, 14 lb.	12.2	0.4	5.9	0.2
Total ration	23.0	1.9	11.4	0.7

$$\text{The nutritive ratio is } \frac{11.4 + (2.25 \times 0.7)}{1.9} \text{ or } 1:6.8$$

This ration, except being a trifle low in dry substance, comes very close to satisfying the standard. Of course, in many cases, especially until one has had considerable practice in the calculation of rations, the trial ration may have to be modified several times before the ration conforms with the standard. However, by applying his practical knowledge and the rules in Chapter VII, the student should not have much difficulty in calculating balanced rations.

Other rations are calculated according to the Wolff-Lehmann standard in the same general manner. It should be borne in mind, however, that as previously mentioned, other factors, such as the proportion of concentrates to roughages, the general practicability, and the cost of the ration, as well as its content of digestible nutrients also must be taken into consideration.

In view of modern investigation, certain modifications

must be made to the Wolff-Lehmann standards to adapt them to American conditions. In practically every instance the amount of dry substance prescribed is 10 to 20 per cent too high. The protein prescribed is from 10 to 40 per cent too high, the greatest difference being in the cases of fattening and working animals and, consequently, the nutritive ratio is too narrow. This is due to the fact that the early students of animal nutrition thought that fattening and work were produced largely or entirely at the expense of the protein of the ration. This of course makes the Wolff-Lehmann standard for these classes of animals less valuable. But little attention should be given to the fat content of the ration, it being considered satisfactory if the requirements for protein and carbohydrates are fulfilled.

Henry and Morrison[1] have recently suggested modifications of the Wolff-Lehmann standards for dairy cows, beef cattle, horses, sheep, and hogs. These standards attempt to correct the objections to the original Wolff-Lehmann standards, and their use is recommended in preference to the older standards. The Henry-Morrison standards are given in Table 33 of the Appendix.

The Armsby Standard. — Perhaps the simplest and among the most accurate standards for the maintenance, growth, and fattening of cattle and sheep are those presented by Armsby of the Pennsylvania Station.[2] A modification of his standard for dairy cows is presented by Van Norman.[3] These standards are based principally upon the work of Armsby in this country and upon that of Kellner in Germany. They are given in Table 34 of the Appendix.

[1] "Feeds and Feeding," pp. 134 and 669.
[2] U. S. Dept. of Agr. Farmers' Bul. 346.
[3] Penn. Exp. Sta. Bul. 114.

The Armsby standards express the requirements of farm animals in pounds of digestible true protein (not crude protein) and in therms of net energy. Instead of giving separate standards for all the different classes of farm animals, Armsby gives standards for maintenance and for growth. Inasmuch as any excess of feed above maintenance may be used for fattening or milk production, he gives the amount of nutrients above the maintenance requirements necessary to produce a pound of gain or a pound of milk. Thus, the standards for fattening and for milk production vary with the amount of gain or with the amount of milk produced. To determine the standard for a fattening animal, one adds 3.5 therms for each pound of daily gain to the energy requirement for maintenance, as all the net energy above the maintenance requirement may be used for the production of flesh and fat. The protein requirement of an immature fattening animal is, according to Armsby, the same as that of a growing animal of the same weight, and the protein requirement of a mature fattening animal is the same as the protein requirement for maintenance. Armsby recommends that a 1000-pound ruminant should receive 20 to 30 pounds, or an average of 25 pounds, of dry substance per day. A horse should have somewhat less. The amounts of digestible true protein and of net energy in the common feedingstuffs as presented by Armsby are given in Table 31 of the Appendix. For example, if one desires to calculate a ration for a 1000-pound steer gaining two pounds per day, the first step is to determine the requirements. From Table 34 of the Appendix, it is seen that the requirements of a 1000-pound steer gaining 2 pounds per day are 1.8 pounds of digestible protein and 13.0 therms of net energy. As the

second step, we will assume a trial ration consisting of 10 pounds of corn and 8 pounds of clover hay. Referring to Table 31 of the Appendix, it is found that the digestible protein and net energy in this ration are as follows:

	Dry Substance	Digestible Protein	Net Energy
	Lb.	*Lb.*	*Therms*
Corn, 10 lb.	8.91	0.68	8.88
Clover hay, 8 lb.	6.78	0.43	2.78
Total ration	15.69	1.11	11.66

Comparing the trial ration with the standard, we find that it is low in both protein and energy. As the third step, we will add 2 pounds of cottonseed meal, as it is high in both protein and energy. The ration then contains the following nutrients:

	Dry Substance	Digestible Protein	Net Energy
	Lb.	*Lb.*	*Therms*
Corn, 10 lb.	8.91	0.68	8.88
Clover hay, 8 lb.	6.78	0.43	2.78
Cottonseed meal, 2 lb.	1.84	0.70	1.68
Total ration	17.53	1.81	13.34

This ration, although a trifle low in dry substance, fulfills the requirements of the Armsby standard.

In calculating a ration for a dairy cow according to the

Armsby standard, one adds to the requirements for maintenance, 0.05 pound of digestible protein and 0.3 therm of net energy for each pound of 4 per cent milk produced. For example, one wishes to calculate a ration for a 900-pound cow giving 22 pounds of approximately 4 per cent milk. According to Table 34 of the Appendix, the requirement is as follows:

	Digestible Protein	Net Energy
	Lb.	*Therms*
For maintenance of 900-lb. cow . . .	0.45	5.7
Addition for 22 lb. of milk	1.10	6.6
Total requirement	1.55	12.3

As a trial ration, we will assume 3 pounds of ground corn, 40 pounds of corn silage, and 15 pounds of clover hay. This ration contains the following nutrients:

	Dry Substance	Digestible Protein	Net Energy
	Lb.	*Lb.*	*Therms*
Ground corn, 3 lb. . . .	2.7	0.20	2.7
Corn silage, 40 lb. . . .	10.2	0.48	6.6
Clover hay, 15 lb. . . .	12.7	0.81	5.2
Total ration	25.6	1.49	14.5

Obviously this ration is too high in dry substance and energy. Consequently, 10 pounds of silage are deducted from the ration, which then has the following composition:

	Dry Substance	Digestible Protein	Net Energy
	Lb.	*Lb.*	*Therms*
Corn silage, 30 lb.	7.6	0.36	4.9
Clover hay, 15 lb.	12.7	0.81	5.2
Ground corn, 3 lb.	2.7	0.20	2.7
Total ration	23.0	1.37	12.8

This ration is low in protein but about right in energy. Consequently, a pound of linseed meal is substituted for a pound of the ground corn, as the linseed meal contains considerably more protein and about the same amount of energy as corn. The ration is as follows:

	Dry Substance	Digestible Protein	Net Energy
	Lb.	*Lb.*	*Therms*
Corn silage, 30 lb.	7.6	0.36	4.9
Clover hay, 15 lb.	12.7	0.81	5.2
Linseed meal, 1 lb.	0.9	0.28	0.8
Ground corn, 2 lb.	1.8	0.13	1.8
Total ration	23.0	1.58	12.7

This ration satisfactorily fulfills the Armsby standard.

Van Norman [1] has proposed a modification of the Armsby standard for dairy cows by taking into account the quality as well as the quantity of the milk. For every variation of 0.1 per cent from a standard fat content of 4 per cent, the amount of digestible protein is increased or decreased, as the case may be, 0.0005 lb., and the energy, 0.008 therm.

[1] Penn. Exp. Sta. Bul. 114.

Thus one calculates the requirements for a 1250 pound cow giving 40 pounds of 3.5 per cent milk as follows:

	DIGESTIBLE PROTEIN	NET ENERGY
	Lb.	*Therms*
To produce 1 lb. of 4 per cent milk	0.0500	0.30
Deduct for decrease of 0.5 per cent in fat .	0.0025	0.04
To produce 1 lb. of 3.5 per cent milk . . .	0.0475	0.26
To produce 40 lb. of 3.5 per cent milk . . .	1.9	10.4
To maintain a 1250-lb. cow	0.6	7.0
Total requirement	2.5	17.4

The ration is then formulated in the usual manner.

Other Standards. — Inasmuch as a considerable number of feeding standards have been proposed, and as a number of investigations upon the requirements of farm animals for different purposes have been reported recently, it may be of value to discuss some of them.

Requirements for Maintenance. — A maintenance ration is one just sufficient to prevent any loss or gain of tissues in the animal body when there is no production. Theoretically a maintenance ration supplies just enough digestible protein to furnish the necessary amino acids for the repair of the protein tissues of the body, and just enough net energy to carry on the vital processes. It supplies the quantity of feed necessary to simply support the animal when doing no work and when yielding no material product. Although in practical feeding simple maintenance is usually (though not always) avoided, nevertheless a knowledge of the maintenance requirement is necessary in order to use many of the

feeding standards, especially those for fattening animals and those for milk production. Considerable work has been done upon the maintenance requirement of cattle, while but little has been done upon that of other farm animals.

After a careful study of the experiments upon this subject, it seems that the averages given in Table 10 represent the maintenance requirement of the farm animals with a fair degree of accuracy.

TABLE 10. — MAINTENANCE REQUIREMENTS OF FARM ANIMALS

	LIVE WEIGHT	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT	TOTAL NUTRIMENT[1]	NET ENERGY
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Therms*
Cattle . . .	1000	0.6	7.0	0.1	8.0	6.5
Horses . . .	1000	0.6	—	—	—	7.0
Sheep . . .	100	0.07	—	—	—	0.9
Hogs . . .	100	0.08	0.3 to 0.4	0.3	0.54	1.2

Requirements for Growth. — Growth consists of an increase in the size of the muscles, bones, organs, etc., of the body. Thus growth is essentially an increase in the amount of protein tissue of the body, although some fat will also be formed, the amount depending upon the amount and nature of the ration. The principal sources of the protein tissue are the protein and mineral matter of the feed. The rate of growth in the young animal is quite high, but decreases as the animal becomes older. In the mature animal practically all growth is confined to the skin, hair, hoofs, and horns. Consequently, the younger an animal is the

[1] Digestible protein plus digestible carbohydrates plus 2.25 times digestible fat.

more protein there should be in the ration, the amount decreasing with the age of the animal until it reaches maturity. Thus especial attention should be given to the protein content of the rations of all growing animals, remembering that it is better to feed a little too much protein than not enough. In addition to the quantity of protein, the quality of the protein should also be considered, in order to make sure that the ration is not deficient in any of the essential amino acids.

If the animals are to be used for meat or work, especial emphasis need not be laid upon the carbohydrates and fat or energy content of the growing ration, so long as it is sufficient. However, if they are to be used for breeding purposes, care should be taken to limit the amounts of carbohydrates and fat of the ration, or the animals may become so fat as to produce barrenness. This is often the case with show animals which have become too fat.

Mineral matter, especially calcium and phosphorus, is absolutely essential to the proper development of the growing animal. Ordinarily, except sometimes in the case of pigs, a properly balanced ration will contain sufficient phosphorus, as most of the nitrogenous feeds are high in phosphorus. If a legume hay is fed, there probably will be sufficient calcium in the ration. Otherwise additional calcium or phosphorus must be supplied by adding feeds which are rich in these elements. In case of pigs, it is usually considered good practice to allow them free access to a mineral mixture. (See page 79).

Haecker, at the Minnesota Experiment Station,[1] after many years of experimentation, proposes the following table as expressing the requirements of growing fattening cattle.

[1] Unpublished data.

TABLE 11. — HAECKER'S STANDARD FOR GROWING FATTENING CATTLE

Dry substance and digestible nutrients daily per 1000 lb. live weight

LIVE WEIGHT	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
100	12.8	2.90	5.5	3.00
200	21.8	3.05	11.6	0.55
300	24.2	2.43	12.4	0.63
400	22.1	1.97	11.1	0.60
500	21.7	1.90	11.1	0.60
600	21.1	1.85	10.8	0.60
700	20.5	1.81	10.4	0.54
800	19.5	1.80	10.0	0.52
900	18.4	1.80	9.4	0.50
1000	17.9	1.64	9.5	0.48
1100	16.5	1.43	9.1	0.44
1200	15.7	1.40	8.8	0.46

This standard supplies less protein and other nutrients than the Henry-Morrison, the Wolff-Lehmann and the Armsby standards for growing cattle. Experiments at the Illinois Experiment Station [1] by Mumford, Grindley, Hall, Emmett, Bull and Allison, show that two-year old steers may be successfully fattened on less protein than provided by the Haecker standard.

Investigations at the Illinois Experiment Station by Bull and Emmett indicate that the Wolff-Lehmann and Armsby standards for growing lambs are too high in protein. The standard for protein given in Table 12 is recommended by them.[2]

[1] Unpublished data.
[2] Ill. Agr. Exp. Sta., Bul. 166.

TABLE 12. PROTEIN REQUIREMENTS OF GROWING LAMBS (BULL AND EMMETT)

WEIGHT OF LAMB	DIGESTIBLE CRUDE PROTEIN PER 100 POUNDS
Lb.	*Lb.*
50– 70	0.32
70– 90	0.27
90–100	0.23
110–150	0.17

The Wolff-Lehmann standard for carbohydrates and fat, and the Armsby standard for energy may be accepted as approximately correct.

Dietrich,[1] formerly of the Illinois Experiment Station, suggests the standard given in Table 13 for growing pigs which are to be used for breeding purposes.

TABLE 13.—REQUIREMENTS OF GROWING HOGS (DIETRICH)

AGE OF PIGS	DIGESTIBLE PROTEIN PER 100 LB. LIVE WEIGHT	DIGESTIBLE CARBOHYDRATES PER 100 LB. LIVE WEIGHT
	Lb.	*Lb.*
8 weeks	0.50	2.2
15 weeks	0.55	2.4
19 weeks	0.45	2.4
26 weeks	0.50	2.4
30 weeks	0.35	2.4
38 weeks	0.40	2.4
2 years	0.20	2.4

The Henry-Morrison standards in Table 33 of the Appendix are quite valuable. In calculating rations for hogs, it is

[1] Ill. Agr. Exp. Sta. Cir. 126, 133, and 153.

recommended that Table 30 of the Appendix be used as representing the digestible nutrients in the feeds.

Savage and Henry and Morrison have presented standards for growing horses. The *Henry-Morrison* standard is given in Table 33 of the Appendix. According to Savage [1] growing horses from 6 months to $2\frac{1}{2}$ years of age should receive 18 pounds of dry substance, 1.7 pounds of digestible protein, and 12.0 pounds of total nutriment per 1000 pounds live weight. The ration should have a nutritive ratio of 1 : 6.1.

Requirements for Pregnant Animals. — The development *of the fœtus in the dam requires protein and mineral matter.* Hence the ration of the mature pregnant animal should contain protein and mineral matter in addition to the maintenance requirements. In case of a young pregnant animal, which is still growing, additional protein and mineral matter above the ordinary requirements must be supplied or the fœtus will be only imperfectly developed at the expense *of the tissues of the dam. If the pregnant animal is pro*ducing milk, or is working, in addition to carrying a fœtus, additional energy as well as protein and mineral matter should be supplied. For example, a mare which is bred, is suckling a foal, and is doing ordinary farm work should have a ration containing more protein and energy than the mare or gelding which is working only.

Requirements for mature breeding ewes, mature brood sows, and mature brood mares doing no work are given by the Wolff-Lehmann and Henry-Morrison standards. In feeding breeding animals care should be taken not to get them too fat, as this often produces barrenness in the female and sterility in the male.

[1] Cornell Agr. Exp. Sta. Bul. 321.

Requirements for Fattening. — Fattening consists of a storage of animal fat in the cells of the various tissues of the body, especially in the tissues of the abdominal cavity and in the connective tissues just under the skin and between the muscles.

In the practical feeding of animals intended for meat production it is difficult and unnecessary to draw any sharp line between growth and fattening, especially in view of the increasing tendency to fatten and market cattle and hogs before they are mature. It is sufficient to say that if the ration contains a surplus of nutrients above the requirements of the animal for maintenance and growth, the surplus up to a certain limit may be used for the production of fat.

We have learned that the principal sources of body fat are the carbohydrates and fat of the feed, although any surplus of protein in the ration may serve also for the production of fat. Consequently, in feeding fattening animals, the amount of protein in the ration is of major importance, while the amount of carbohydrates and fat or of energy is of minor importance, as long as enough of them is supplied. Inasmuch as the most rapid fattening is usually the cheapest fattening, a practical method of formulating the rations of fattening animals is to fulfill the protein requirement and then give them all the carbohydrates and fat they will consume.

The idea of the amount of protein required for fattening has undergone considerable modification within the last few years. The idea of the older investigators in animal nutrition regarding the production of body fat was that the protein of the feed was its sole source. Consequently, the

amounts of protein supplied by some of the older feeding standards, such as the Wolff-Lehmann, are greatly exaggerated. The results of more modern investigations indicate that, in the case of immature animals, no more protein is required for fattening than for growth. Hence, no more protein is recommended for immature fattening animals than for growing animals. But little more protein is required for fattening mature animals than for the maintenance of such animals, provided the excess of carbohydrates does not cause a decrease in the digestibility of the ration. It has already been explained that if the nutritive ratio of the ration is wider than 1 to 10 or 12, the digestibility will be decreased.

For fattening immature cattle no more protein is recommended than is supplied by the standards for growing cattle. The Henry-Morrison and the Haecker standards for growing, fattening steers are probably not far from the truth. Investigations with fattening mature cattle indicate that 1.0 lb. of digestible crude protein per 1000 pounds live weight is sufficient.

For the energy, carbohydrate, and fat requirements of fattening cattle, we can do no better than recommend the Armsby, Wolff-Lehmann, Henry-Morrison, or Haecker standards.

Late experiments indicate that 0.15 pound or even less of digestible crude protein per 100 pounds live weight is sufficient for mature fattening sheep. For fattening lambs, Bull and Emmett[1] recommend the same standard for protein as given in Table 12 for growing lambs. From 1.8 to 2.0 therms of net energy per 100 pounds live weight should be sufficient for fattening.

[1] Ill. Agr. Exp. Sta. Bul. 166.

Dietrich[1] recommends the standard for fattening market hogs given in Table 14.

TABLE 14. — REQUIREMENTS OF FATTENING HOGS (DIETRICH)

AGE OF HOGS	DIGESTIBLE PROTEIN PER 100 LB. LIVE WEIGHT
Weeks	*Lb.*
8	0.60
15	0.70
19	0.60
26	0.65
30	0.30

According to Dietrich they should have 2.4 lb. of digestible carbohydrates per 100 pounds live weight at the beginning of the feeding period. This amount is increased gradually to 2.8 pounds. After this they are kept just below full-feed. A little more fat than is found in the ordinary farm rations is recommended by Dietrich.

As in the case of fattening cattle and sheep, the protein requirements of the Wolff-Lehmann standard for fattening hogs are too high. Their protein requirement for growing breeding stock, and the amounts of carbohydrates and fat as prescribed by their standard for growing and fattening hogs probably represent approximately the requirements of fattening hogs. The Henry-Morrison standards for fattening pigs also are quite valuable.

Requirements for Work. — The idea of the early investigators in animal nutrition was that the protein was the source of muscular work, consequently the old standards, such as the Wolff-Lehmann, are too high in this nutrient. Inasmuch

[1] Ill. Agr. Exp. Sta. Cir. 126, 133, and 153.

as work is done at the expense of the carbohydrates and fats of the ration, theoretically the amount of protein supplied for the maintenance of a horse should be sufficient for the same horse when doing work, as work is done primarily at the expense of the carbohydrates and fat of the feed, the protein not being drawn upon as long as the other nutrients are present in sufficient amounts. However, in actual practice, usually it is desirable to feed more protein than the maintenance requirement, because, as we have already seen, a ration with a very wide nutritive ratio is not as thoroughly digested as one containing more protein. Kellner states that a nutritive ratio of 1 : 8 or 1 : 10 is sufficient to prevent any decrease in the digestibility of the ration.

The requirements for mature work horses are given in the Wolff-Lehmann, the Henry-Morrison, and the Kellner standards. For convenience, we have followed the custom of Armsby and expressed the Kellner standard in terms of digestible protein and net energy. The Kellner standard for a 1000-lb. horse, thus expressed, is given in Table 15.

TABLE 15. — REQUIREMENTS OF WORK HORSES (KELLNER)

	TOTAL DRY SUBSTANCE	DIGESTIBLE PROTEIN	NET ENERGY
	Lb.	*Lb.*	*Therms*
Light work	18-23	1.2	9.8
Medium work	21-26	1.6	12.4
Heavy work	23-28	2.2	16.0

Any of these standards should be valuable.

It should be borne in mind that, on account of his limited digestive capacity, the horse, especially when doing hard

work, can handle but a relatively small amount of roughage. Hence, the greater part of the energy should be furnished in the form of concentrates.

Horses which have not completed their growth and horses which have a large amount of work to do in a short time, as racing and driving horses, should have larger amounts of protein than those prescribed.

Requirements for Milk Production. — The average chemical composition of milk is as follows: water, 87.1 per cent; ash, 0.7 per cent; protein, 3.2 per cent; fat, 3.9 per cent; and carbohydrates (milk sugar), 5.1 per cent. As the animal *organism does not have the power to construct protein from* carbohydrates and fats, the protein of the feed is the sole source of the milk protein. However, the fat of the feed is not the sole source of the milk fat, as cows may produce normal amounts of butter fat on a ration containing only traces of fat. It is probable that the carbohydrates, fats, and any surplus of protein in the feed may all be used for the production of milk sugar and butter fat, although their principal source is the carbohydrates of the feed.

In formulating a standard for milk production, not only the weight of the cow but the quantity and quality of the milk should be taken into consideration. The requirement for maintenance of course depends upon the size of the cow, while the requirement above maintenance varies with the amount and richness of the milk; *i.e.* the percentage of fat which it contains.

The requirements for dairy cattle have been determined more accurately than those of any other class of animals. Among the more recent investigators who have studied the requirements for milk production are Armsby and Van Nor-

man, whose standards have been discussed, Haecker, Savage, Woll and Humphrey, and Eckles.

The Haecker standard for dairy cows has been developed by Haecker of the Minnesota Experiment Station [1] during many years of experimentation. He holds that the feed requirements of the dairy cow vary not only according to her weight and the quantity of the milk yield, but also according to the quality of the milk.

According to Haecker, a 1000-pound cow requires for maintenance 0.7 lb. of digestible crude protein, 7.0 lb. of digestible carbohydrates, and 0.1 lb. of digestible fat. For each pound of 4 per cent milk the Haecker standard requires the addition of 0.054 lb. of digestible crude protein, 0.24 lb. of digestible carbohydrates, and 0.021 lb. of digestible fat in addition to the maintenance requirement. If the milk contains less than 4.0 per cent of fat, smaller amounts of nutrients are prescribed, while if the milk contains more than 4.0 per cent fat, larger amounts of nutrients are prescribed. The amounts of digestible nutrients to produce one pound of milk containing various percentages of butter fat are given in Table 16.

TABLE 16. — HAECKER'S STANDARD FOR MILK PRODUCTION

FAT IN MILK	PROTEIN	CARBOHYDRATES	FAT
Per Cent	*Lb.*	*Lb.*	*Lb.*
2.5	0.0446	0.176	0.0151
2.6	.0451	.180	.0155
2.7	.0455	.185	.0159
2.8	.0460	.190	.0163
2.9	.0464	.194	.0166
3.0	.0469	.199	.0170
3.1	.0474	.203	.0174

[1] Bul. 130, 140.

TABLE 16. — HAECKER'S STANDARD FOR MILK PRODUCTION
(*Continued*)

FAT IN MILK	PROTEIN	CARBOHYDRATES	FAT
Per Cent	*Lb.*	*Lb.*	*Lb.*
3.2	.0478	.207	.0178
3.3	.0483	.212	.0181
3.4	.0486	.216	.0185
3.5	.0492	.221	.0189
3.6	.0501	.225	.0193
3.7	.0511	.220	.0196
3.8	.0520	.234	.0200
3.9	.0530	.238	.0204
4.0	.0539	.242	.0208
4.1	.0546	.247	.0211
4.2	.0553	.251	.0215
4.3	.0558	.255	.0218
4.4	.0565	.260	.0222
4.5	.0572	.264	.0226
4.6	.0579	.268	.0230
4.7	.0584	.272	.0233
4.8	.0591	.276	.0236
4.9	.0597	.280	.0240
5.0	.0604	.284	.0243
5.1	.0611	.288	.0247
5.2	.0618	.291	.0250
5.3	.0625	.295	.0253
5.4	.0632	.299	.0256
5.5	.0639	.302	.0259
5.6	.0644	.307	.0263
5.7	.0651	.310	.0266
5.8	.0656	.314	.0269
5.9	.0663	.318	.0273
6.0	.0668	.322	.0276
6.1	.0679	.326	.0279
6.2	.0689	.330	.0283
6.3	.0700	.334	.0286
6.4	.0710	.338	.0289
6.5	.0721	.342	.0293
6.6	.0724	.345	.0296
6.7	.0728	.349	.0299
6.8	.0731	.353	.0302
6.9	.0735	.357	.0305
7.0	.0738	.359	.0308

For example, to calculate a ration according to the Haecker standard for a 900-pound cow, giving 20 pounds of milk daily containing 5 per cent of butter fat, the process is as follows: (1) determine the maintenance requirement for a 900-pound cow; (2) add to the maintenance requirement the requirement to produce 20 pounds of 5 per cent milk; and (3) calculate a ration to conform with this standard. Thus a cow weighing 900 pounds requires 0.63 lb. of digestible protein, 6.30 lb. of digestible carbohydrates, and 0.09 lb. of digestible fat for maintenance. According to Haecker, to produce one pound of 5 per cent milk requires the consumption of 0.060 lb. of digestible crude protein, 0.28 lb. of digestible carbohydrates, and 0.024 lb. of digestible fat, in addition to the maintenance requirement. Thus the total requirement to produce 20 pounds of 5 per cent milk is calculated as follows:

	Digestible Protein	Digestible Carbohydrates	Digestible Fat
	Lb.	*Lb.*	*Lb.*
For maintenance	0.63	6.30	0.09
To produce 20 lb. of 5 per cent milk	1.22	5.60	0.50
Total	1.85	11.90	0.59

The ration is then calculated in the same manner as described under the discussion of the Wolff-Lehmann standards.

The Savage Standard for Dairy Cows. — Savage, at the Cornell University Experiment Station,[1] after extensive experiments, suggests the following standard for the mainte-

[1] Bul. 323.

nance of a 1000-pound cow: digestible protein, 0.7 lb., and total nutriment (*i.e.* digestible protein plus digestible carbohydrates plus 2.25 times digestible fat), 7.925 lb. To produce 1 pound of milk of varying degrees of richness, he suggests the addition of digestible protein and total nutriment as given in Table 17.

TABLE 17. — SAVAGE'S STANDARD FOR MILK PRODUCTION

FAT IN MILK	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Per Cent	*Lb.*	*Lb.*
2.5	0.0527	0.2574
2.6	.0535	.2629
2.7	.0543	.2685
2.8	.0551	.2743
2.9	.0559	.2812
3.0	.0567	.2870
3.1	.0575	.2928
3.2	.0583	.2987
3.3	.0591	.3055
3.4	.0599	.3115
3.5	.0608	.3185
3.6	.0616	.3243
3.7	.0624	.3312
3.8	.0632	.3369
3.9	.0640	.3428
4.0	.0648	.3497
4.1	.0656	.3555
4.2	.0664	.3612
4.3	.0672	.3671
4.4	.0680	.3729
4.5	.0689	.3787
4.6	.0697	.3842
4.7	.0705	.3890
4.8	.0713	.3945
4.9	.0721	.3992
5.0	.0729	.4048
5.1	.0737	.4105
5.2	.0745	.4150

TABLE 17. — SAVAGE'S STANDARD FOR MILK PRODUCTION
(Continued)

FAT IN MILK	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Per Cent	*Lb.*	*Lb.*
5.3	.0753	.4209
5.4	.0761	.4253
5.5	.0770	.4311
5.6	.0778	.4355
5.7	.0786	.4413
5.8	.0794	.4469
5.9	.0802	.4517
6.0	.0810	.4572
6.1	.0818	.4619
6.2	.0826	.4676
6.3	.0834	.4721
6.4	.0842	.4791
6.5	.0851	.4835
6.6	.0859	.4882
6.7	.0867	.4926
6.8	.0875	.4984
6.9	.0883	.5040
7.0	.0891	.5075

Concerning this standard, Savage makes the following statement: "The writer would further recommend that a cow be fed according to this standard when her condition has become normal after calving. Then the grain ration should be increased 1 pound per day and the cow watched closely for one week, a careful record being kept of her milk and fat production. If, at the end of the week, the cow's health is good and she has increased in fat or milk production sufficiently to pay for the increase in feed, another pound per day should be added to the grain ration as before, and so on until the cow is getting all the feed she will eat up clean, if she shows in her product that she will pay for the increase each time."

Thus the requirements of a cow weighing 1100 pounds and producing 35 pounds of 3.2 per cent milk are as follows:

	Digestible Protein	Total Nutriment
	Lb.	*Lb.*
For maintenance	0.7700	8.7175
For 35 lb. of 3.2 per cent milk . .	2.0405	10.4545
Total	2.8105	19.1720

The ration is then calculated in the usual manner, keeping in mind that the total nutriment is obtained by multiplying the fat by 2.25, and adding to it the protein and carbohydrates.

The Woll and Humphrey Standard for Dairy Cows. — Woll and Humphrey, of the Wisconsin Experiment Station,[1] have presented a standard for dairy cows based upon the live weight of the cow and the amount of butter fat produced daily. Their standard is given in Table 18.

Thus to determine the requirements of a 900-pound cow giving 20 pounds of 5 per cent milk daily, one first determines the amount of butter fat produced daily, which in this case is 1.0 pound. From Table 18, it is seen that a 900-pound cow producing 1.0 pound of butter should have 22.4 pounds of dry substance, 2.04 pounds of digestible protein, and 15.0 pounds of total digestible substance (digestible protein + digestible carbohydrates + digestible fat). The ration is then calculated in the usual manner.

[1] Research Bul. 13.

Table 18. — Woll and Humphrey's Standard for Dairy Cows

Live weight *Lb.*	Production of Butter Fat per Day, Pounds							
	Dry cows	0.0-0.5 *Lb.*	0.5-0.75 *Lb.*	0.75-1.0 *Lb.*	1.0-1.25 *Lb.*	1.25-1.5 *Lb.*	1.5-1.75 *Lb.*	1.75-2.0 *Lb.*
TOTAL DRY SUBSTANCE REQUIRED, POUNDS								
800	10.0	13.7	16.2	18.6	21.1	23.5	26.0	28.4
900	11.3	15.0	17.5	19.9	22.4	24.8	27.3	29.7
1000	12.5	16.2	18.7	21.1	23.6	26.0	28.5	30.9
1100	13.8	17.5	20.0	22.4	24.9	27.3	29.8	32.2
1200	15.0	18.7	21.2	23.6	26.1	28.5	31.0	33.4
1300	16.3	20.0	22.5	24.9	27.4	29.8	32.3	34.7
1400	17.5	21.2	23.7	26.1	28.6	31.0	33.5	35.9
1500	18.8	22.5	25.0	27.4	29.9	32.8	34.7	37.2
DIGESTIBLE PROTEIN REQUIRED, POUNDS								
800	0.56	1.04	1.35	1.66	1.97	2.29	2.60	2.91
900	.63	1.11	1.42	1.73	2.04	2.36	2.67	2.98
1000	.70	1.18	1.49	1.80	2.11	2.43	2.74	3.05
1100	.77	1.25	1.56	1.87	2.18	2.50	2.81	3.12
1200	.84	1.32	1.63	1.94	2.25	2.57	2.88	3.19
1300	.91	1.39	1.70	2.01	2.32	2.64	2.95	3.26
1400	.98	1.46	1.77	2.08	2.39	2.71	3.02	3.33
1500	1.05	1.53	1.84	2.15	2.46	2.78	3.09	3.40
TOTAL DIGESTIBLE SUBSTANCE[1] REQUIRED, POUNDS								
800	6.3	9.0	10.7	12.5	14.2	16.0	17.7	19.5
900	7.1	9.8	11.5	13.3	15.0	16.8	18.5	20.3
1000	7.9	10.6	12.3	14.1	15.8	17.6	19.3	21.1
1100	8.7	11.4	13.1	14 9	16.6	18.4	20.1	21.9
1200	9.5	12.2	13.9	15.7	17.4	19.2	20.9	22.7
1300	10.3	13.0	14.7	16.5	18.2	20.0	21.7	23.5
1400	11.1	13.8	15.5	17.3	19.0	20.8	22.5	24.3
1500	11.9	14.6	16.3	18.1	19.8	21.6	23.3	25.1

[1] Digestible protein plus digestible carbohydrates plus digestible fat.

The Eckles Standard for Dairy Cows. — Eckles, of the Missouri Station,[1] after very elaborate experimentation, recently has published a standard for dairy cows. He recommends the Armsby standard for maintenance, to which he adds the amounts of digestible true protein and net energy per pound of milk as indicated in Table 19.

TABLE 19.— REQUIREMENTS PER POUND OF MILK OF VARYING RICHNESS (ECKLES)

FAT IN MILK	DIGESTIBLE PROTEIN	NET ENERGY
Per Cent	*Lb.*	*Therms*
3.0	0.050	0.26
3.5	0.052	0.28
4.0	0.055	0.30
4.5	0.058	0.33
5.0	0.062	0.36
5.5	0.066	0.40
6.0	0.070	0.45
6.5	0.075	0.50

The requirement per pound of milk suggested for herd-feeding, where it is not practical to take into account the richness of the milk of each individual, is given in Table 20.

TABLE 20. — REQUIREMENTS PER POUND OF MILK FROM DIFFERENT BREEDS (ECKLES)

BREED	DIGESTIBLE PROTEIN	NET ENERGY
	Lb.	*Therms*
Holstein	0.050	0.26-0.28
Shorthorn, Ayrshire, Brown Swiss	0.055	0.28-0.30
Jersey, Guernsey	0.066	0.40-0.45

[1] Research Bul. 7.

The protein content and energy values of feedingstuffs as presented by Armsby (Table 31, Appendix) are used in calculating rations according to the Eckles standard.

Summary of Standards for Dairy Cows. — It is of considerable interest to compare the different standards for milk production. For the maintenance of a 1000-pound cow, the different standards are given in Table 21.

TABLE 21. — SUMMARY OF STANDARDS FOR MAINTENANCE OF DAIRY COWS

STANDARD	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT	NET ENERGY
	Lb.	*Lb.*	*Therms*
Armsby	0.6[1]	—	6.0
Haecker	0.7	7.9	—
Savage	0.7	7.9	—
Woll-Humphrey	0.7	8.1	—
Eckles	0.6[1]	—	6.0
Average	0.66	7.97	6.0

For the production of 1 pound of 4 per cent milk, the standards are given in Table 22.

TABLE 22. — SUMMARY OF STANDARDS FOR PRODUCTION OF ONE POUND OF 4 PER CENT MILK

STANDARD	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT	NET ENERGY
	Lb.	*Lb.*	*Therms*
Armsby	0.050[1]	—	0.3
Haecker	0.054	0.34	—
Savage	0.065	0.35	0.3
Woll-Humphrey	0.056	0.31	—
Eckles	0.055[1]	—	0.3
Average	0.056	0.33	0.3

[1] True protein, not crude protein.

These results, obtained from careful, independent investigation, agree with each other remarkably well and their average probably represents the requirements for milk production as closely as they may be represented by a mathematical expression.

Requirements for Wool Production. — Inasmuch as wool is composed largely of protein, a small amount of protein is necessary for wool production. Armsby,[1] after reviewing the available experiments, concludes that 0.14 lb. of protein daily per 1000 pounds live weight should be added to the other protein requirements for wool production. In experiments by Grindley, Emmett, Coffey, and Bull at the Illinois Station,[2] feeding large amounts of protein did not produce any more wool in the case of fattening lambs than when only a medium amount was fed. When sheep in good, thrifty condition receive sufficient nutrients for the other functions of the body, it is probable that the additional requirements for wool production may be neglected.

The Feed Unit System of Calculating Rations. — Although it has been used but little in this country, the feed unit system is used quite extensively in Denmark, where it originated, and in other Scandinavian countries. It is used almost entirely for dairy cows, though to a slight extent for the other classes of farm animals.

Unlike the other standards already discussed, the feed unit system does not take into account either the total digestible nutrients or the net energy values of the feeds. Instead, the different feeds, after many carefully conducted feeding experiments, were given equivalent values, regarding

[1] U. S. Dept. of Agr. Bur. of Anim. Ind. Bul. 143.
[2] Unpublished data.

a pound of mixed grain like corn, wheat, or barley as the standard by which all other feeds are compared. Thus corn, wheat, and barley were all given a value of "1 unit" per pound after it was found that equal amounts of these feeds could be substituted for each other in the ration without materially affecting the amount of production by the animal. It was found that one pound of corn could be replaced by 0.8 pound of cottonseed meal without decreasing or increasing the production. Consequently, it takes only 0.8 pound of cottonseed meal to equal one unit. The amounts of other feeds required to equal one unit were determined in the same way.

The amounts of different feeds required to equal one feed unit are given in Table 23, in so far as they have been determined.

TABLE 23.—AMOUNTS OF DIFFERENT FEEDS EQUIVALENT TO ONE FEED UNIT

FEEDINGSTUFF	FEED REQUIRED TO EQUAL ONE UNIT	
	Average *Lb.*	Range *Lb.*
Corn, wheat, rye, barley, hominy feed, dried brewers' grains, wheat middlings, peas, dried beet pulp, dry matter in roots	1.0	—
Cottonseed meal, peanut meal	0.8	—
Linseed meal, dried distillers' grains, gluten feed, soy beans	0.9	—
Wheat bran, oats, malt sprouts, molasses grains	1.1	—
Alfalfa meal; alfalfa-molasses feed	1.2	—
Alfalfa hay, clover hay	2.0	1.5–3.0
Mixed hay, oat hay, oat and pea hay, barley and pea hay, red top hay	2.5	2.0–3.0
Timothy hay, prairie hay, sorghum hay	3.0	2.5–4.0

TABLE 23. — AMOUNTS OF DIFFERENT FEEDS EQUIVALENT TO ONE FEED UNIT (*Continued*)

FEEDINGSTUFF	FEED REQUIRED TO EQUAL ONE UNIT	
	Average *Lb.*	Range *Lb.*
Corn stover, corn fodder, straw	4.0	3.5– 6.0
Green alfalfa	7.0	6.0– 8.0
Corn silage	6.0	—
Wet brewers' grains	4.0	—
Sugar beets	7.0	—
Carrots	8.0	—
Rutabagas	9.0	8.0–10.0
Field beets, rape	10.0	—
Turnips, mangels, fresh beet pulp	12.5	10.0–15.0
Pasture, per day	—	8–12[1]

The following feeding standard[2] for dairy cows has been proposed by Hansson, of the Royal Swedish Academy for a 1000-pound cow per day:

For maintenance, 0.65 lb. digestible protein and 6.6 feed units.
For production, 0.045 lb. to 0.05 lb. digestible protein and ⅓ feed unit per pound of milk.

Thus a ration for a 1100-pound cow giving 40 pounds of milk is calculated as follows:

	DIGESTIBLE PROTEIN	FEED UNITS
	Lb.	
Required for maintenance	0.72	7.3
Required for production	2.00	13.3
Total requirement	2.72	20.6

[1] Depending upon kind and condition.

[2] After Woll, "Productive Feeding of Farm. Animals," p. 80.

A ration consisting of $7\frac{1}{2}$ pounds of ground corn, 3 pounds of linseed oil meal, 10 pounds of clover hay, and 30 pounds of corn silage would contain the following amount of digestible protein and feed units:

	Digestible Protein	Feed Units
	Lb.	
$7\frac{1}{2}$ lb. corn contain	0.59	7.5
3 lb. oil meal contain	0.92	3.3
10 lb. clover hay contain . . .	0.71	5.0
30 lb. corn silage contain . . .	0.39	5.0
Total ration contains . . .	*2.61*	*20.8*

This ration satisfies the requirements of the standard.

The feed unit system is especially valuable as a means of comparing the efficiency of production by different cows, as it is quite easy to calculate the amount of milk produced per feed unit. It is the official standard of many cow-testing associations in Europe.

Self-feeders. — Any study of feeding standards and balanced rations is incomplete without a discussion of the "cafeteria system" of balancing rations. By the cafeteria system *the animals are given free access to different feeds* and allowed to eat as much or as little of each feed as they choose. This is done usually by means of a self-feeder, which is a feed box so built as to hold a considerable quantity of concentrated feed, a portion of which is accessible to the animals at all times, and at the same time protect the large bulk of the feed from the weather and keep the animals from mussing over it.

Figure 24 shows a self-feeder for cattle as designed by Mumford of the Illinois Station. Figure 25 shows a self-feeder for hogs as designed by Carmichael of the Illinois Station.

For Hogs. — Evvard of Iowa has conducted the most elaborate experiments with self-feeders for hogs. Evvard found that, in feeding hogs for the market, self-fed hogs made more rapid and more economical gains than hand-fed hogs. In another experiment seven lots were fed as follows: Lot 1, according to the Wolff-Lehmann standard; Lot II, according to the Kellner standard; Lot III, according to the Dietrich standard with water at free will; Lot IV, according to Dietrich with water weighed; Lot V, self-fed corn, middlings, and tankage; Lot VI had free choice of the same feeds offered them three times daily; and Lot VII had free choice of the same feeds offered them twice daily. The free-choice and self-fed lots made the fastest and most economical gains, requiring considerable less grain for 100 pounds of gain than those fed according to accepted standards.

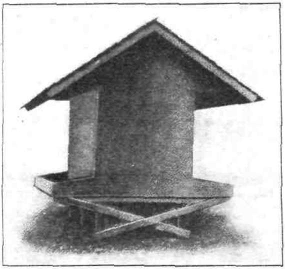

Fig. 24. — A self-feeder for cattle. (Mumford, Beef Production.)

Professor Evvard states that in case of breeding gilts it may be necessary to limit the corn either by hand feeding

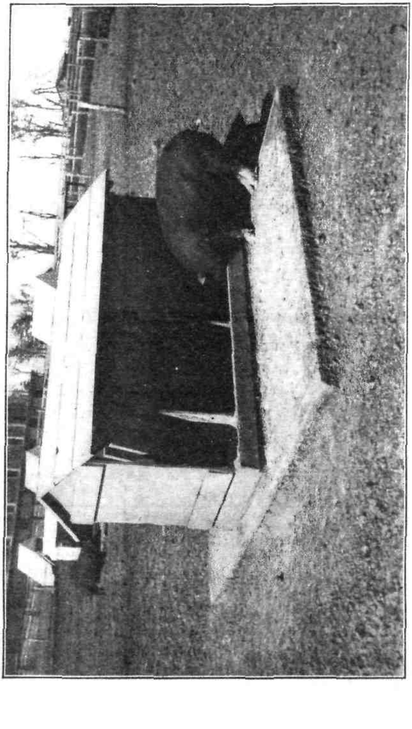

Fig. 25. — A self-feeder for hogs. (Illinois Experiment Station.)

or by mixing it with ground alfalfa hay. From these and other experiments the Iowa Station concludes that the pig's *own appetite, with free choice of feeds before him at all times*, seems to be the best feeding standard for swine.

For Cattle. — Self-feeders are perhaps more generally used for fattening cattle than for any other class of live stock. In a census taken by Mumford and Hall at the Illinois Experiment Station[1] among the larger cattle feeders of Illinois, it was found that 28 per cent of them were using the self-feeder. If one includes the smaller feeders perhaps it would be found that a smaller per cent than this are using the self-feeder.

The objections to the use of the self-feeder for cattle are as follows:

1. It cannot be safely used to start cattle on feed. Thus they should be hand-fed until they are on full-feed, or the hay may be ground or cut finely and mixed with the concentrates until they are on full-feed. Unless considerable care is taken in getting them on full-feed there will be danger of founder.

2. Even under the most favorable conditions cattle require slightly more feed to produce a pound of grain when self-fed.

3. It is difficult to furnish the nitrogenous concentrate in the self-feeder and it often is fed by hand.

4. The feeder is liable to become careless and not pay enough attention to the cattle. An old German adage states, "The eye of the master fattens his cattle."

5. Unless the feeder is properly constructed there will be a loss of feed by slobbering or mussing over it.

[1] Cir. 98.

6. The cost of a feeder large enough to accommodate 10 or 12 steers will be between $35 and $50.

7. There will be less roughage consumed than when hand feeding is practiced.

The advantages of the self-feeder for cattle are as follows:

1. It is more economical of labor.
2. It is more reliable than a careless man.
3. Cattle will eat more and make greater gains and consequently require a shorter feeding period.
4. When properly constructed, there is little feed wasted.

Thus it seems that, although the self-feeder for cattle is not advisable for all conditions, yet there certainly is a place for it upon some corn belt farms, especially where labor is expensive and unreliable and where roughage is scarce.

For Sheep. — Self-feeders for sheep are used to a large extent by men who make a practice of feeding large numbers of western lambs or wethers. They are used to only a small extent by small feeders, as they reduce the gains and waste feed owing to the fact that the sheep is very particular about eating feed which has been slobbered over by other animals. Most good sheepmen, however, have a "lamb creep" in which feed is kept in an ordinary feed trough for suckling lambs.

For Horses. — Self-feeders are never used for horses except when a "creep" is provided for sucking and weanling foals. Then the feed is kept in a feed box or trough rather than in a self-feeder.

CHAPTER IX

GRAINS AND SEEDS

Introduction

It has been stated that feedingstuffs may be divided into concentrates and roughages on the basis of their content of net energy and digestible nutrients.

For convenience of study, concentrates and roughages may be divided further into classes and sub-classes on the basis of their physical characteristics and sources, according to the following outline:

Concentrates:

- I. Grains and seeds
  - 1. Cereals
  - 2. Legumes
  - 3. Oil-bearing seeds
- II. Cereal by-products
- III. Oil by-products
- IV. Packinghouse by-products
- V. Miscellaneous concentrates

Roughages:

- I. Hays
  - 1. Legumes
  - 2. Grasses
- II. Fodders and stovers
- III. Straws

IV. *Pasture or forage, and soiling crops*
 1. Legumes
 2. Grasses
V. Silage
VI. Miscellaneous roughages

Grains and seeds may be subdivided into three sub-classes, viz: (1) cereal grains, (2) legume seeds, and (3) oil-bearing seeds.

CEREAL GRAINS

A cereal may be defined as any plant belonging to the grass family which yields a farinaceous (*i.e.* floury or mealy)

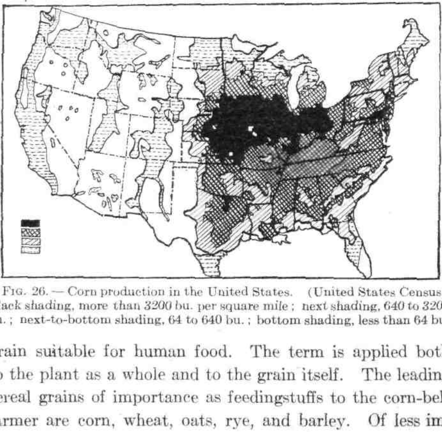

FIG. 26. — Corn production in the United States. (United States Census.) Black shading, more than 3200 bu. per square mile; next shading, 640 to 3200 bu.; next-to-bottom shading, 64 to 640 bu.; bottom shading, less than 64 bu.

grain suitable for human food. The term is applied both to the plant as a whole and to the grain itself. The leading cereal grains of importance as feedingstuffs to the corn-belt farmer are corn, wheat, oats, rye, and barley. Of less importance are emmer, speltz, sorghum, millet, and rice.

Corn. — Corn is not only the most important concentrate of the corn-belt, but it is also the most important single feedingstuff grown in the United States. The reason for this lies in the fact that, under favorable conditions, corn will produce upon the same acreage a greater amount of digestible nutrients than almost any other crop. It will produce about twice as much as any of the other cereals. Table 24 clearly illustrates this point.

TABLE 24.—YIELD OF DIGESTIBLE NUTRIENTS PER ACRE

Crop	Yield	Digestible Nutrients per Acre
		Lb.
Corn — Grain	50 bu.	3795
Stover	1½ tons	
Oats — Grain	40 bu.	2045
Straw	1½ tons	
Barley — Grain	40 bu.	2278
Straw	1 ton	
Wheat — Grain	20 bu.	1661
Straw	1 ton	
Soy beans — Grain	15 bu.	1392
Straw	1 ton	
Cowpeas — Grain	12 bu.	1332
Straw	1 ton	
Clover hay	2½ tons	2335
Alfalfa hay	4 tons	4152
Cowpea hay	2½ tons	2490
Timothy hay	1½ tons	1437
Shock corn	3½ tons	2681
Corn silage	10 tons	3260
Green corn	10 tons	2660
Sorghum (green)	10 tons	2500
Sugar beets	20 tons	4480
Mangels	20 tons	2680
Rape	10 tons	2080

Over two-thirds of the corn crop of the United States is produced by the following states: Illinois, Iowa, Kansas, Nebraska, Missouri, Indiana, and Ohio. Consequently, these states are often spoken of as "the corn-belt." Although corn is grown to a considerable extent in many other states, in no instance is the production larger than the consumption. In many states little or no corn is grown. Over 90 per cent of the total corn crop of the United States is produced by 21 states.

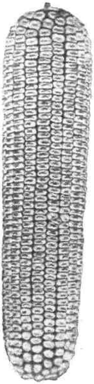

FIG. 27. — An ear of dent corn. (Livingston, Field Crop Production.)

There are two races of corn of special interest to the stock feeder, viz., flint corn and dent corn. Flint corn is harder, smaller, and yields less than dent corn. It is especially adapted to localities with a season too short to produce the dent varieties. It is grown largely in the northern and eastern parts of the United States. In the corn-belt, dent corn is practically the only race of corn used for stock feeding, owing to the larger yield. There is little difference in the chemical composition and feeding value of flint and dent corn.

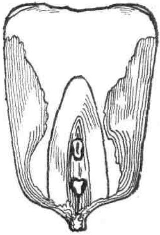

FIG. 28. — Cross-section of a kernel of dent corn. (Livingston, Field Crop Production.)

Corn may be of varied colors, yellow and white being the most common. It is often said that yellow corn has a

higher feeding value than white corn, or *vice versa*. However, as a matter of fact, there is no difference in either the chemical composition or the feeding value of white and yellow corn.

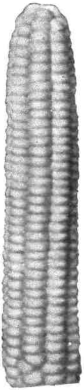

FIG. 29. — An ear of flint corn. (Livingston, Field Crop Production.)

The average chemical composition of corn is as follows: water, 10.6 per cent; ash, 1.5 per cent; crude protein, 10.3 per cent; crude fiber, 2.2 per cent; nitrogen-free extract, 70.4 per cent; and fat, 5.0 per cent. Its net energy value in 88.8 therms per 100 pounds. As shown by its chemical composition and energy value, corn is preëminently a fattening feed. In this respect it is without a rival. It is relatively high in starch and fat, medium in crude protein, and quite low in ash. Furthermore, as has been mentioned already, the principal protein of corn is not satisfactory for growth. Hence corn should be fed to young animals, breeding animals, and milk cows in moderation, and it should be supplemented by feeds rich enough in protein and mineral matter to make up the deficiencies in these nutrients. Corn is a very palatable feed, owing to its high content of fat and its crisp, flinty nature. As a matter of fact it is the most palatable of all the cereals.

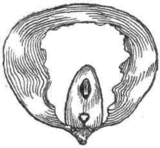

FIG. 30. — Cross-section of a kernel of flint corn. (Livingston, Field Crop Production.)

Corn may be fed in various ways. It is fed as ear corn,

especially to horses and hogs; as broken ears, especially to cattle; as shelled corn, especially to sheep; and as ground corn, especially to milk cows, and to young animals in general. It is also fed as fodder corn, as a forage, and as silage.

For Growing Stock. — In general corn should be used in limited amounts in the feeding of growing animals as it is deficient in muscle- and bone-forming constituents. For such animals, it should be supplemented by concentrates which are rich in protein and mineral matter and by the legume hays.

For calves and growing cattle, corn may comprise from one-fourth to one-half the concentrates of the ration, the remainder of the concentrates being made up of feeding-stuffs containing more protein and mineral matter. If possible, legume hays also should be fed with it. If non-legume roughages are fed, the proportion of corn in the ration should be decreased, and the nitrogeneous concentrates increased. For young calves, corn should be ground. The ears should be broken for older cattle.

In case of foals and young horses, corn should not form more than one-third of the concentrates. Oats, bran, or a little linseed meal should be used with it to make up the deficiency in protein and mineral matter. Young foals should have ground corn, and older colts, ear-corn.

Corn should be fed to growing pigs in limited amounts, supplemented by such nitrogenous feeds as tankage, middlings, linseed meal, skim milk, or clover or alfalfa pasture. From 50 to 90 per cent of the ration, depending upon the amount of protein in the supplement used, may consist of ear corn.

Young lambs should be fed ground corn with ground oats, bran, gluten feed, or linseed meal. As soon as they get their teeth, lambs should have shelled corn or finely broken ear corn. Not over 50 per cent of the concentrates should consist of corn unless it is intended to fatten them. They should have clover or alfalfa as roughage.

For Fattening Stock. — As previously stated, corn is pre-eminently a fattening feed. In fact, it is the best fattening feed available, especially if properly supplemented.

When fed to fattening cattle with clover, alfalfa, or other legume hay, corn may form from 75 to 90 per cent of the concentrates of the ration. When fed with a non-nitrogenous roughage, as timothy hay, corn stover, silage, or straw, the proportion of corn in the concentrates should be reduced. Corn should be supplemented by linseed oil meal, cottonseed meal, gluten meal, or soy beans. It is probably most economical to feed corn to fattening cattle in the form of broken ears, except in case it is fed with silage when it should be shelled. However, when unground corn is fed to fattening cattle, they should be followed by hogs to pick up any lost or undigested grain.

For fattening mature hogs, corn alone may be successfully used, especially if they have access to pasture. Inasmuch as most fattening is done when the hogs are immature, however, corn should be supplemented with such feeds as tankage or middlings. Corn may make up from 75 to 95 per cent of the ration depending upon the amount of protein in the supplementary feed. It is probably most economical to feed ear-corn to fattening hogs, although some authorities advocate shelling and soaking, or grinding corn for fattening hogs weighing 150 to 200 pounds.

For fattening lambs and sheep, shelled or finely broken ear-corn may form the sole concentrate if fed with clover or alfalfa hay. If fed with a non-nitrogenous roughage, as timothy hay or corn stover, linseed meal, cottonseed meal, gluten feed, or some other nitrogenous concentrate should furnish 25 per cent of the concentrates of the ration.

For Breeding Stock. — The same precautions, only perhaps in a less degree, should be taken in feeding corn to breeding stock as in feeding it to growing animals. Especially is *this true during pregnancy. An excess of corn in the ration* not only does not furnish sufficient protein and mineral matter for the proper development of the fœtus, but it also is too heating and too fattening.

Breeding cattle require little or no corn when good pasture is available. In winter, it should not make up over one-half the concentrates. Perhaps the best way to utilize corn for breeding cows is in the form of silage properly supplemented.

In the case of brood mares, either pregnant or nursing a foal, corn should not form more than one-third of the concentrates. Oats or bran with a little linseed meal should be used with it in order to supply the deficiency in protein and mineral matter. In connection with this statement, it should be noted that many of the brood mares of the corn-belt have no other concentrate than corn, and no other roughage than timothy hay. If considerable corn is used in the ration, some good, clean clover or alfalfa hay, or clover or blue grass pasture should be available.

Corn is too fattening, too heating, and too deficient in bone- and muscle-forming constitutents to justify its use in large quantities by breeding hogs. It may be used, however, up to the extent of one-third to one-half the concentrates

of the ration, the remainder being made up of such feedingstuffs as ground oats, wheat middlings, and bran with a little tankage. Blue grass, clover, or alfalfa pasture makes a good supplement to corn.

For breeding ewes, corn should not make up more than 50 per cent of the concentrated portion of the ration. Even less than this usually will give better results. A mixture of such feedingstuffs as oats, bran, or linseed meal should make up the remainder of the concentrates of the ration.

For Milk Cows. — Inasmuch as the milk cow requires large amounts of protein and mineral matter for milk production, the ration should be correspondingly rich in these nutrients. Consequently, corn ordinarily should not make up more than 50 per cent of the concentrates, even when fed with nitrogenous roughages. The remainder of the concentrates should consist of a mixture of several of such feedingstuffs as oats, gluten feed, linseed oil meal, cottonseed meal, and bran. When fed with a non-nitrogenous roughage, not over one-fourth or one-third of the concentrates should consist of corn. Corn usually is fed to milk cows in the form of ground corn, or corn and cob meal, which is the entire ear, coarsely ground.

For Work Horses. — It was thought formerly that corn was not a proper feed for work horses, oats being preferable. However, it was found by Carmichael at the Ohio Experiment Station [1] that when mixed hay was fed to mature geldings at general farm work, ear corn was as efficient, pound for pound, as oats. Moreover, the use of corn was more economical. At the Missouri Experiment Station,[2] Trowbridge found that mature mules doing farm work were

[1] Bul. 195. [2] Bul. 114.

kept 28 per cent more economically on a ration of corn and mixed hay than on a ration of oats and mixed hay. However, at the Kansas Experiment Station,[1] McCampbell found that oats were better than corn when fed with either timothy or prairie hay. When fed with alfalfa hay, corn gave as good results and was one-third cheaper than a ration of oats and prairie hay. Also actual practice seems to show that, in the case of mature working horses, corn may be fed in large amounts for extended periods of time with practically as good results as when oats comprise the grain ration. This is of considerable practical importance as, at ordinary prices, corn makes a much cheaper ration than oats.

Soft corn *is corn which has been killed by frost while the* grain is still immature. Consequently it contains too much moisture for storage or shipment. It may contain as much as 30 or 40 per cent water. The only use for soft corn is to feed it as soon as possible to cattle, hogs, or sheep. It is not a safe feed to use for horses, and considerable care should be exercised in getting the other farm animals upon a full feed of soft corn. In an experiment with fattening steers by Kennedy, Dinsmore, Rutherford, and Smith at the Iowa Station,[2] it was found that soft corn was equal to sound corn in feeding value, pound for pound of dry substance. In feeding soft corn better results will be obtained *by feeding three or four times a day as an animal cannot* eat enough dry substance to obtain the best results if fed only twice a day.

Wheat. — Wheat generally is considered too valuable as a human food to be of particular importance as a stock

[1] Bul. 186. [2] Bul. 75.

feed. Under exceptional conditions, however, as in case of an abnormally cheap price or poor quality, wheat may be utilized profitably as a feed for farm animals. Some feeders make it a rule to feed their wheat when it is worth only ten per cent more than corn. It is estimated by the United States Department of Agriculture that ordinarily about two per cent of the total wheat crop is utilized as feed for farm animals.

There are two kinds of wheat, viz., spring and winter wheat. Winter wheat is the ordinary wheat of the corn-belt. It is sown in the fall and harvested the following summer. Spring wheat is sown in the spring and harvested that summer. It is grown especially in Minnesota, Iowa, Nebraska, the Dakotas, Montana, and in central and western Canada, where the climate is too severe for winter wheat. There is little or no difference in the chemical composition and feeding value of winter and spring wheat.

The average chemical composition of wheat is as follows: water, 10.5 per cent; ash, 1.8 per cent; crude protein, 11.9 per cent; crude fiber, 1.8 per cent; nitrogen-free extract, 71.9 per cent; and fat, 2.1 per cent. Its net energy value is 82.6 therms per 100 pounds. Wheat differs from corn in chemical composition in having slightly more protein and mineral matter, and less than half the amount of fat. Its energy value is somewhat less. However, wheat is not flinty and crisp like corn, but chews up into a gummy, unpalatable mass, so that, except in case of sheep, it is unsuited for feeding purposes without previously being ground and mixed with some coarser feed, such as bran or oats.

For Growing Stock. — Wheat is somewhat better adapted than corn for growing animals as it contains more protein

and mineral matter. However, wheat alone is not a satisfactory ration for growing animals. At the Wisconsin Experiment Station,[1] wheat and mineral matter were not sufficient to produce normal growth in pigs. However, the addition of a small amount of milk produced satisfactory growth. Thus, wheat should be fed to immature animals with other feeds, particularly those high in protein.

For calves and young cattle, ground wheat is an excellent feed. The addition of oats up to 50 per cent of the concentrates usually improves the ration. For colts, wheat should be ground and mixed with bran or oats. It is not satisfactory when fed alone. For young pigs, wheat is superior to corn. It should be ground and fed in a slop with water or, preferably, with skim milk or buttermilk. Wheat is also excellent for lambs. It need not be ground for them, however.

For Fattening Stock. — In general, wheat is somewhat less valuable for fattening than corn. However, it produces a carcass superior to that of corn-fed animals.

For fattening cattle, ground wheat is not quite equal, pound for pound, to ground corn. A mixture of the two grains is better than either when fed alone. Wheat-fed steers have less fat and more bright-colored lean meat than corn-fed steers. For fattening hogs, corn and wheat are about equal, but the quality of the meat of the wheat-fed hogs is superior. A mixture of ground wheat and corn is better than either fed alone. Wheat-meal should be fed in a slop with either water or milk. It was found by Bliss and Lee at the Nebraska Experiment Station[2] that grinding increased the value for hogs about one-third. Soaking either ground or unground wheat made no appreciable differ-

[1] Jour. Biol. Chem. XIX, 1914, p. 373. [2] Bul. 144.

ence in the results. Frozen, slightly burned or charred, or shrunken and damaged wheat is nearly as valuable for hog feeding as the marketable grain. For sheep and lambs, wheat is excellent during the early stages of fattening, but corn is about 10 per cent more valuable during the latter stages of fattening. It is excellent as a feed for show animals on account of the firm flesh which it produces. Frozen or otherwise damaged wheat often is fed to sheep. Wheat need not be ground for sheep.

For Breeding Stock. — Wheat is better than corn for breeding stock, owing to the larger amount of bone- and muscle-forming constitutents in it. Further, it is not so fattening nor so heating as corn. However, wheat should not form the sole ration of breeding animals. At the Wisconsin Experiment Station,[1] heifers and cows which were fed on wheat, wheat gluten, and wheat straw produced weak or dead calves. The milk flow was decreased, and the cows themselves were not normal. However, when alfalfa hay replaced the wheat straw of the ration, the deficiencies of the ration were overcome.

For milk cows, ground wheat is fully equal or superior to ground corn. It should be mixed with other concentrates, including a nitrogenous concentrate.

For work horses, wheat alone is unsatisfactory. Ground and mixed with bran and oats, it forms a satisfactory ration.

Oats. — Next to corn, oats are the most extensively grown cereal in the United States. They are naturally adapted to a cooler climate than corn, but they can be grown successfully in a warmer climate provided the rainfall is sufficient. Thus they are grown over a large area.

[1] Research Bul. 17.

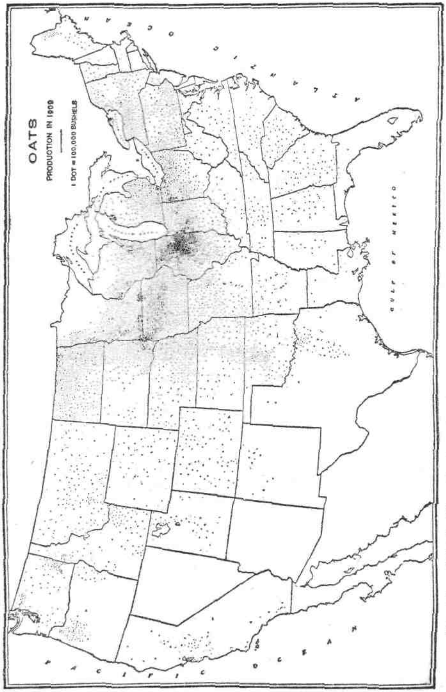

FIG. 31. — Distribution of oat production in the United States. (United States Census, 1910.)

Viewed from the standpoint of general adaptation for feeding live stock, no cereal compares with oats, as they can be fed with safety to practically all classes of animals.

The average chemical composition of oats is as follows: water, 10.0 per cent; ash, 3.0 per cent; crude protein, 11.8 per cent; crude fiber, 9.5 per cent; nitrogen-free extract, 59.7 per cent; and fat, 5.0 per cent. Their net energy value is 66.3 therms per 100 pounds. Oats contain about twice as much ash, and a little more crude protein than corn. Furthermore, the mixed proteins of oats are more satisfactory for maintenance and growth. Oats contain considerably less energy than corn. Their high content of crude fiber, due largely to the loose, light husk which incloses the kernel, gives them such volume that an animal rarely suffers from eating too much of them, although they may cause choking if eaten too rapidly. Oats are fed both whole and ground or rolled. They are usually ground for very young animals, for dairy cows, for horses at very hard work, and for horses with poor teeth.

Low grade, discolored oats are often bleached by treatment with sulphurous acid fumes in order to raise the market grade. Horsemen claim that bleached oats are sometimes injurious.

For Growing Stock. — The chemical composition and energy value of oats indicate that they are a growing, rather than a fattening feed. In addition, the physical structure of oats makes them a particularly safe feed on account of the slight danger of causing digestive disturbances by their use. Their cost is practically the only factor which may limit their use.

For calves and young cattle, oats may be ground and fed either as the sole concentrate, or in combination with ground

corn or barley and some nitrogenous concentrate, as linseed meal or bran. For foals, oats should be ground or crushed. They should make up a large part of the concentrates of colts and young horses. Ground oats with the hulls sifted out may be fed to young pigs, but are not much used for that purpose as cheaper rations will usually produce better results. Ground oats with the hulls sifted out are especially good for very young lambs. The whole grain is also very good for lambs that are to be kept for breeding purposes.

For Fattening Stock. — Owing to their small amount of nitrogen-free extract and their low energy value, oats are much inferior to corn, wheat, and barley for fattening, and should not be used for this purpose unless they are very cheap in price.

If their cost permits, they may be used for cattle in the early part of the fattening period to the extent of one-fourth or one-half the concentrates of the ration. After the cattle are on full-feed, a more fattening concentrate should be substituted for them. Although it is thought by many cattle feeders that oats are essential to the successful production of baby beef, it has been found by Rusk at the Illinois Experiment Station [1] that this is not true. In fact, the use of oats considerably increased the cost of gains. They may be of value, however, in getting the calves on full-feed, but are not essential for this purpose.

For Breeding Stock. — Owing to their large amount of ash, their relatively large amount of protein, and their physical structure, oats are an excellent feed for breeding animals, although they are usually quite expensive. The use of oats in the rations of breeding cows, brood mares,

[1] Unpublished data.

and breeding ewes may be limited only by their cost. They also may be used quite extensively in the rations of brood sows, but a cheaper substitute usually may be found to answer this purpose.

For milk cows there is no better feed than oats. They may constitute the whole or any part of the concentrates in the ration, depending upon their price. Wheat bran, ground corn, and ground oats in equal parts make a good combination of concentrates for dairy cows. Even when more expensive than corn, it usually is profitable to use some oats in the ration. As a supplement to corn, oats are more valuable, pound for pound, than bran. Unless bran is used in the ration, however, some nitrogenous concentrate, as linseed oil meal, cottonseed meal, or gluten feed should be used with the corn and oats. The amount of the nitrogenous concentrate will depend largely upon the nature of the roughage, *i.e.* whether it is nitrogenous or non-nitrogenous.

For Work Horses. — Concerning the use of oats as a horse feed, Gay [1] makes the following statement: "The concentrate best adapted to the feeding of horses is oats; on account of both chemical and physical composition, they stand first in this class. They not only meet the protein and carbohydrate requirement best, but the hull is an advantage, in so extending the kernel as to insure more complete digestion. Besides, there seems ample reason for believing that oats improve the fettle, especially of harness and saddle horses." The pointed end of the oat hull is sometimes clipped off, reducing the proportion of hull and increasing the weight per bushel. Clipped oats are used as a fancy horse feed.

[1] "Productive Horse Husbandry," p. 235.

Oats are an especially safe feed for horses, as the hull gives them such volume that the animal rarely suffers from gorging. For horses at very hard work, they should be crushed or ground. For horses with good teeth not doing too hard work, they may be fed whole. A grain ration consisting of two-thirds oats and one-third corn, barley, rye, or wheat, is considered quite satisfactory. As stated previously, for economical purposes, oats may be largely or entirely supplemented by corn in the case of mature work horses. New and musty oats always should be avoided.

Rye. — Rye is more closely related to wheat than to any other cereal although differing from it in several particulars. It is one of the hardiest of the cereals. It can be grown on land too low in fertility to give a good yield of corn, wheat, oats, or barley. It also will withstand weather conditions which would prove disastrous to wheat. For these reasons it has been called the grain of poverty. In general, it may be regarded as a surer crop than wheat.

The average chemical composition of rye is as follows: water, 11.6 per cent; ash, 1.9 per cent; crude protein, 10.6 per cent; crude fiber, 1.7 per cent; nitrogen-free extract, 72.5 per cent; and fat, 1.7 per cent. Its net energy value is 81.7 therms per 100 pounds. Although rye has nearly the same chemical composition and energy value as wheat, it is 5 to 10 per cent less valuable for stock feeding, owing to its very low degree of palatability. It should always be ground and thoroughly mixed with more palatable feeds for all classes of animals except sheep.

For Growing Stock. — In general rye should be used in only limited amounts for growing stock. It should not form over one-third the concentrates of the ration. It should

always be ground except for sheep. It is very doubtful if it is profitable to use rye very extensively, if at all, for growing animals except in case of hogs.

For Fattening Stock. — Owing to its lack of palatability, rye is not especially valuable as a feed for fattening cattle and sheep. Although but little used for hog feeding in this country, it is used quite extensively in Denmark. For hogs, rye is about equal to barley in feeding value and about 10 per cent less valuable than corn. It should be ground and fed as a thin slop. In prolonged feeding, it should be fed with corn or barley, and more nitrogenous concentrates. Otherwise hogs soon tire of it.

FIG. 32. — Ergot in a head of rye. (Duggar, Southern Field Crops.)

For Breeding Stock. — Rye should not be used to any marked extent in the rations of breeding stock. When it is used, care should be taken that it is not infected with the fungus, ergot, which may cause abortion.

For Milk Cows. — Rye meal is slightly less valuable than corn for milk cows. It may be fed in limited amounts with other concentrates. If more than three pounds are fed daily, the quality of the milk and butter may be affected, as too much rye gives them a bitter flavor. Rye which is infected with ergot should not be used.

For Work Horses. — Rye may be fed to work horses, provided it is ground and mixed with other concentrates. It should not form more than one-third of the concentrates. Care should be taken that it is not infected with ergot, especially in the case of brood mares.

Barley. — Barley is grown successfully in a wider range of climate than any other cereal. However, it seems to thrive best in a warm, dry climate. It is grown principally on the Pacific coast and in the northern part of the United States, where corn is not especially successful, although it can be grown in the corn-belt. It is an excellent substitute for corn where the latter crop cannot be grown successfully. The best grades of barley are used principally for brewing, and the lower grades are used for stock feeding.

FIG. 33. — A head of barley. (Livingston, Field Crop Production.)

As in the case of oats, discolored barley is often bleached with sulphurous acid fumes to brighten it up and make it grade higher.

The average chemical composition of barley is as follows: water, 12.0 per cent; ash, 2.5 per cent; crude protein, 11.4 per cent; crude fiber, 5.7 per cent; nitrogen-free extract, 66.6 per cent; and fat, 1.8 per cent. Its net energy value is 80.7 therms per 100 pounds. It is richer in bone- and muscle-forming constituents than corn, and slightly lower in fattening constitutents. It is not as palatable as corn. The composition of hulled barley is almost identical with that of wheat.

For feeding purposes, barley should be rolled rather than ground, as the ground barley-meal forms a pasty mass in the mouth of the animal, which is difficult to masticate, swallow, and digest.

For Growing Stock. — Due to its higher content of protein and mineral matter, and its lower content of carbohydrates, barley may be used to a greater extent than corn in the rations of growing animals.

For calves and growing cattle, barley should always be fed in combination with other concentrates, such as bran, or

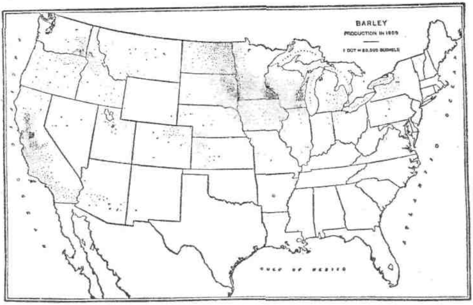

FIG. 34. — Distribution of barley production in the United States. (United States Census, 1910.)

oats, or both, together with a little linseed meal. Other nitrogenous feeds may be substituted in part for the oats or bran. Ordinarily, barley should not form over one-third of the concentrates of such a ration. It should be fed with clover, alfalfa, or other legume hay as roughage. Barley, if fed with oats, bran, and linseed meal, proves satisfactory for colts and young horses. For growing pigs it is much better than corn. It should be properly supplemented by

nitrogenous concentrates. Barley and oats make a good combination for very young lambs.

For Fattening Stock. — In general, barley is slightly less valuable for fattening than corn, due to its lower content of carbohydrates and fat, and to its lower degree of palatability.

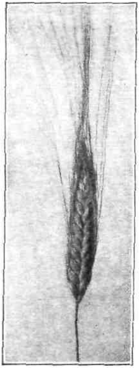

FIG. 35. — A head of emmer. (Livingston, Field Crop Production.)

For beef cattle, barley may form three-fourths of the concentrates, the other fourth being made up of nitrogenous concentrates. It should be fed with a legume hay. For fattening hogs, barley is about 10 per cent less valuable than corn. It produces a higher quality of pork, however. In Great Britain and northern Europe, barley is the leading feed for producing pork of fine quality. If fed in combination with corn, wheat middlings, skim milk, tankage, or alfalfa or clover pasture, barley is one of the best feeds for pork production. It is especially valuable for the production of bacon, as it produces a firmer flesh containing more lean and less fat than the flesh produced by corn. If fed with clover or alfalfa hay, barley may furnish all the concentrated part of the ration of fattening lambs or sheep. However, it is usually more satisfactory to substitute corn for a third of the barley. If fed with a non-nitrogenous roughage, additional protein in the form of linseed meal or cottonseed meal should be given. It should be fed whole to sheep.

For Breeding Stock. — Barley may be used quite extensively in the rations of breeding animals, — up to one-third or one-half of the concentrates, especially when fed with clover or alfalfa hay.

For Milk Cows. — In Denmark a mixture of one part of barley and two parts of oats is regarded as the best available concentrate for dairy cattle. If fed with ground oats or bran and a more nitrogenous concentrate, the barley constituting not over one-half the mixture, it is nearly as valuable as corn.

For Work Horses. — Barley is used quite extensively as the sole grain feed for horses on the Pacific coast, where corn and oats do not flourish. Also it is used extensively in Europe. Some authorities claim that barley is as valuable a feed for horses as oats. When the horses' teeth are good and the labor is not too severe, it may be fed whole. Otherwise, it should be rolled or crushed.

FIG. 36. — A head of speltz. (Livingston, *Field Crop Production.*)

Emmer and speltz are quite similar grains which belong to the wheat family, although in appearance they closely resemble barley. They are especially valuable in the semi-arid regions of the West and Northwest, as they are quite resistant to drought. They are similar in composition to barley, but are somewhat less valuable for feeding purposes.

The sorghums are divided into two groups, the non-saccharine, or grain sorghums, and the saccharine, or sweet sorghums, depending upon whether or not the stems con-

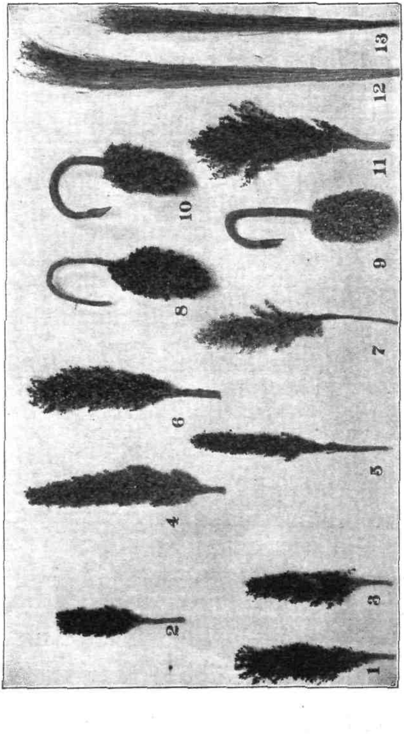

FIG. 37. — Heads of the principal types of sorghums. (Montgomery, The Corn Crops.) 1, amber; 2, orange; 3, *sumac*; 4, *red* kafir; 5, pink kafir; 6, blackhull kafir; 7, shallu; 8, milo; 9, white durra; 10, brown durra; 11, brown kowliang; 12, standard broom-corn; 13, dwarf broom-corn.

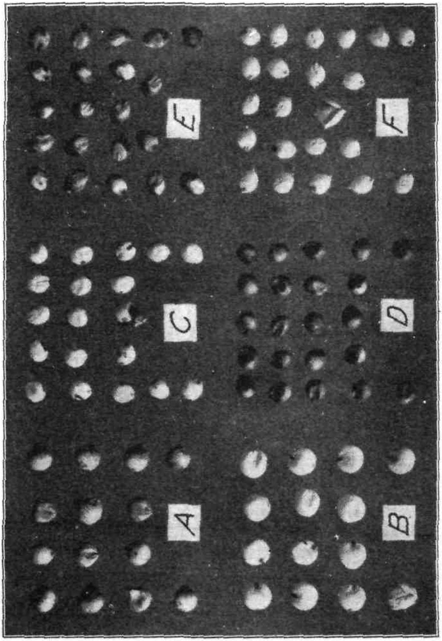

FIG. 38. — Seeds of the principal types of grain sorghums. (Montgomery, The Corn Crops.) *A*, milo; *B*, white durra; *C*, black hull kafir; *D*, red kafir; *E*, brown kowliang; *F*, shallu.

tain sugar in appreciable amounts. Both the sweet and grain sorghums are used to a large extent for human food in Asia and Africa. In this country the grain sorghums are grown to considerable extent, and the sweet sorghums to a slight extent, for stock-feeding. The sweet sorghums are not used for grain but for forage. Being drought-resistant, the grain sorghums are especially valuable as substitutes for corn in the semi-arid states of the West and Southwest, such as Kansas, Oklahoma, and Texas.

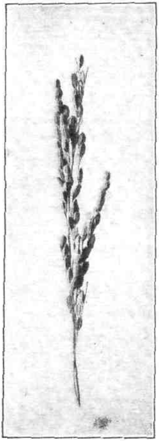

FIG. 39. — A panicle of rice. (Livingston, *Field Crop Production.*)

The principal grain sorghums are kafir corn, milo-maize, feterita, kowliang, and shallu. The seeds are small, round, hard, and of various colors. They are borne in large clusters at the top of the stalk of the plant, which somewhat resembles corn in appearance.

The grain contains more carbohydrates, but less protein and fat than corn. It may be used for all classes of live stock and is perhaps about 90 per cent as valuable as corn. It should be threshed and ground for fattening cattle, while it may be fed threshed or in the head to working horses and to sheep. It may be fed unthreshed to idle horses, dairy cows, and young stock in general. It should be threshed and ground for hogs.

The Millets. — Like the sorghums, the millets are grown extensively in Asia and Africa as human food. They are grown sometimes for their seed in the plains region of this country, north of the areas best suited for the sorghums, and are often used as catch-crops in the corn-belt. Millet seed contains more crude fiber and less nitrogen-free extract and fat than corn. Its feeding value is considerably less than that of corn.

FIG. 40. — Ten varieties of cowpeas. (Piper, Forage Plants.)

Rice is grown exclusively in the South for human food. When damaged or cheap in price it may be used for stock-feeding with good results. It is very high in carbohydrates, but is low in protein and fat. It has a feeding value equal to that of corn, and when properly supplemented, may be fed with good results to horses, cattle, sheep, or hogs if the cost will permit.

THE LEGUME SEEDS

The principal legume seeds used in stock feeding are Canada field peas, cowpeas, soybeans, peanuts, and field beans.

The Canada field pea is grown principally in Canada, northern United States, and in some of the Rocky Mountain valleys where the spring and summer heat is not too great.

The field pea is rich in protein and mineral matter. Combined with other feedingstuffs, field peas are eminently fitted as a feed for dairy cows and may make up as much as 50

per cent of the concentrates of the ration. They are also very good, especially in the form of pasture, as a part of the ration of sheep and lambs. With ground corn, bran, or middlings, pea-meal forms an excellent ration for growing and breeding hogs. It should not be fed alone as it is too heavy and indigestible. For fattening hogs it is a satisfactory supplement to corn. Although little used for horse feeding, Gay[1] states that they may be employed profitably in combination with other concentrates.

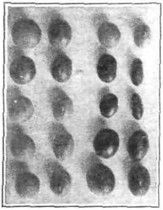

FIG. 41. — Ten varieties of soybeans. (Piper, Forage Plants.)

Cowpeas are grown extensively in the South, and some varieties may be grown successfully in the corn-belt. They often may be profitably grown as a substitute for clover when the latter fails. Another practice is to plant cowpeas with the corn, or sow the peas between the corn rows after the last cultivation, and then "hog down" the corn and peas. The seed pods ripen unevenly, necessitating gathering them by hand. For this reason, the plant is usually grown for hay, silage, or forage rather than for the seed. Cowpeas resemble Canada field peas in chemical composition but are lower in protein and higher in carbohydrates. They are especially valuable for hog feeding.

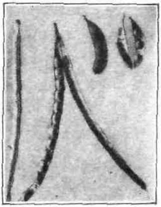

FIG. 42. — Pods of cowpeas and soy beans. (Livingston, Field Crop Production.)

[1] "Productive Horse Husbandry," p. 237.

Soybeans are grown principally in China, but some varieties may be grown successfully in the corn-belt. Henry and Morrison[1] state that no other plant in the United States grown so little at this time as the soybean is so full of promise to agriculture, especially to animal husbandry. They are one of the most valuable substitutes for clover in the corn-belt. They may be used as hay or forage, or the beans may be harvested and fed. The beans are very high in both protein and fat, containing 36.3 and 18.0 per cent respectively. One part of soybeans and two parts of corn with mineral matter make a fairly satisfactory ration for hogs. They are excellent with corn for sheep. Fed to dairy cows, they have a tendency to produce soft butter. Owing to the high value of soybeans as seed, it is doubtful if they can be used economically for stock feeding until their price is lower.

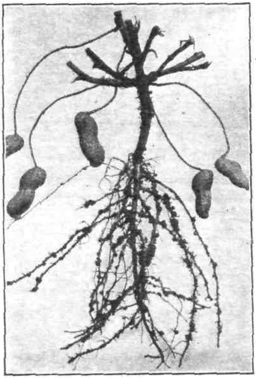

FIG. 43. — Root of peanut. (Livingston, *Field Crop Production.*)

Peanuts are very high in both protein and fat. They are increasing in importance as a feed for hogs in the South, the hogs being turned in when the peanuts are ripe and

[1] "Feeds and Feeding," p. 178.

allowed to forage at will. They are not grown in the corn-belt to any extent.

Field beans are grown principally for human food, but the culls and damaged beans are often available for stock feed in certain sections of the country. Their composition is very similar to that of cowpeas. They may be fed whole in large quantities to sheep, producing a solid flesh of good quality. Better results probably would be obtained by feeding them with corn. For hogs, they should be cooked in salt water and fed with corn or barley, as they produce a soft pork when fed alone.

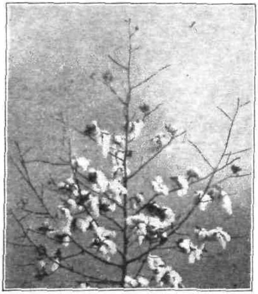

FIG. 44. — A cotton plant. (Livingston, Field Crop Production.)

THE OIL-BEARING SEEDS

Some plants store energy in the seeds in the form of fat or oil rather than as starch. The oil-bearing seeds contain as much as 40 per cent of fat in some cases. They are also quite high in protein. Fat or oil being too valuable for use in large quantities as a stock feed, it usually is pressed or extracted from the seeds, the residue in the form of a cake or meal being used for stock feeding. The use of these by-products will be discussed later. The principal oil-bearing seeds of interest are cottonseed and flaxseed. According to our classification, the soy bean and peanut also fall in this class as well as in the class of the legume seeds.

Cottonseed is obtained after the cotton has been removed by ginning. Formerly, cottonseed was used quite extensively as a stock feed in the South. However, owing to its value as the source of cottonseed oil, it is now not generally fed, although it is still used to a limited extent for feeding steers and dairy cows. Cottonseed should not be fed to hogs.

Flaxseed is also very high in oil. Being the source of linseed oil, it is usually too valuable for ordinary stock feeding. A little ground flaxseed often may be used to advantage in feeding skim milk calves. For ordinary stock-feeding, flaxseed is not as valuable as linseed oil meal, the residue after the removal of the oil.

CHAPTER X

THE CEREAL BY-PRODUCTS

THE cereal by-products, as the name implies, consist of the offal and residues of the cereal grains resulting from the manufacture of flour, starch, meal, breakfast food, and other products for human consumption. They usually contain those parts of the grain which are high in crude fiber, crude protein, and ash, and low in nitrogen-free extract. Inasmuch as the ordinary farm-grown rations are usually high in carbohydrates and low in crude protein and mineral matter, many of the cereal by-products are of considerable importance to the stock feeder.

CORN BY-PRODUCTS

The by-products of corn are principally from the starch and glucose factories, from the distilleries, and from the hominy factories. The starch and glucose by-products are gluten meal, gluten feed, corn bran, and corn germ meal. The distillery by-products are distillers' slops and distillers' dried grains. The by-product from the manufacture of hominy is hominy meal or hominy feed.

In the manufacture of starch and glucose,[1] the corn is first soaked in a warm, very dilute solution of sulphurous acid. It is then ground by being passed with water through mills

[1] Mass. (Hatch) Exp. Sta. Bul. 78.

to carry off the substance in suspension. Degerminating machinery removes the germs, which are dried and crushed

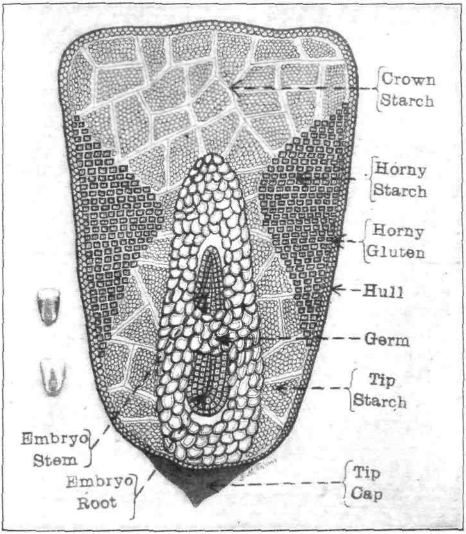

FIG. 45. — Structure of the corn kernel. (Illinois Experiment Station.)

between rollers, and the oil pressed out, leaving the residue in cakes. This is corn germ cake. The cake is usually ground and sold as corn germ meal or corn oil meal. After

degermination the residue of the corn is bolted through sieves separating out the hull and bran, which is sometimes sold under the name of corn bran. The residue, consisting largely of starch and gluten suspended in water, is passed very slowly through long shallow troughs. The starch settles to the bottom, while the gluten floats off into receivers. The gluten is then dried and ground, forming gluten meal.

Gluten meal, or "corn-starch by-product without corn bran," as it is sometimes called, is one of the richest concentrates in crude protein, containing 36.0 per cent. It is also relatively high in fat. It is medium in content of carbohydrates, but low in ash. However, only a small amount of gluten meal is sold on the market as such, most of it being mixed with corn bran and sold as gluten feed.

Gluten feed, or "corn-starch by-product with corn-bran," as it is sometimes called, consists of gluten meal and corn bran ground together. It is lower in protein and higher in crude fiber than gluten meal, due to the presence of the corn bran. Most of the gluten meal and corn bran is marketed in this form. Sometimes the water used in the separation of the starch and gluten is evaporated, and the soluble proteins, mineral matter, and carbohydrates, or the "corn solubles," which it contains are added to the gluten feed.

The chemical composition of gluten feed is as follows: water, 8.5 per cent; ash, 1.9 per cent; crude protein, 25.9 per cent; crude fiber, 7.2 per cent; nitrogen-free extract, 53.3 per cent; and fat, 3.2 per cent. Its net energy value is 79.3 therms per 100 pounds.

For Growing Stock. — For all young animals, gluten meal is more satisfactory than gluten feed, inasmuch as it is less bulky. It should be fed with a little linseed oil meal for

the sake of the laxative effect of the latter. With oats, gluten feed makes a good concentrate for growing cattle. Owing to its deficiency in mineral matter it should not be used in the ration of colts or growing horses. It may be used to advantage in the rations of lambs. Evvard,[1] at the Iowa Station, found that gluten meal or corn oil meal was not a satisfactory supplement to corn for growing pigs.

For Fattening Stock. — Gluten feed may be used as a supplement to less nitrogenous concentrates for fattening all classes of live stock. Under present conditions, however, some cheaper supplement usually may be obtained.

For Breeding Stock. — Gluten feed often may be used to advantage in the ration of breeding animals if its cost will permit. Care should be taken that the ration is not deficient in mineral matter.

For Milk Cows. — Gluten feed may be used quite extensively in the ration of the dairy cow. In fact, this is the principal use made of this feedingstuff. If not too expensive, it may be used profitably to the extent of four or five pounds per day. Too much gluten feed has a tendency to produce soft butter. This may be counteracted by feeding cottonseed meal with it, as the latter tends to produce hard butter.

For Work Horses. — Gluten feed is sometimes fed to the horse. It has the objection that when moistened with saliva it has a tendency to form balls in the mouth and is not palatable. It should not be fed in large quantities, but only as a supplement to corn or some other non-nitrogenous concentrate.

Corn bran is the outer covering of the corn grain. It contains practically all the crude fiber found in the grain.

[1] Unpublished data.

Its feeding value is low and should not be confused with that of wheat bran. Its principal use in stock feeding is as a dilutent of gluten meal to form gluten feed, and as an adulterant of wheat bran.

Corn oil meal, or corn germ meal consists of the germ of the corn after the corn oil has been partially extracted. It is quite high in protein, 23 per cent, and in fat, 10 per cent. Although it is a valuable nitrogenous concentrate, there is but little available on the market. It may be used, especially in the dairy ration, if its cost is not too great. It is lower in feeding value than linseed or cottonseed meal.

Distillers' Slops and Dried Grains. — In the manufacture of whisky and grain alcohol, the rye or corn, as the case may be, is ground and heated with steam in large steel drums in order to thoroughly cook the starch grains. It is then cooled and treated with malt which contains an enzyme which changes part of the starch to maltose or malt sugar. The sugar is then converted to alcohol by the action of yeast, and the alcohol is distilled off, leaving behind a watery residue known as distillers' slops. These slops may be fed to fattening steers at or near the distillery. Such cattle are sold on the market as "distillers." Distillers' slops are also fed to hogs.

In the large distilleries, however, the thicker slops are dried and put on the market as distillers' dried grains. They contain 30.9 per cent crude protein, 10.7 per cent crude fiber, 39.2 per cent nitrogen-free extract, 10.6 per cent fat, and 2.8 per cent mineral matter. Corn makes the best, and rye the poorest, distillers' grains. They are valuable especially as a feed for dairy cows, being superior to gluten feed. As a feed for horses, some authorities reckon them as equivalent

to oats in feeding value. Relatively, they are usually cheaper than either oats or bran. They also may be used satisfactorily for fattening animals, if their price will permit. Owing to their fibrous nature, only small amounts can be utilized by the hog. Distillers' grains should always be used as a supplement to less nitrogenous concentrates.

Distillers' dried grains are often sold on the market under a different name, such as gluten feed or some trade name, in order to hide their true identity, as many people would not buy them under their true name.

Hominy feed, meal, or chop is a mixture of the bran coating, the germ, and a part of the starchy portion of the corn kernel obtained as a by-product in the manufacture of hominy for human consumption. It contains about 11 per cent protein, 5 per cent crude fiber, 65 per cent nitrogen-free extract, and 7 per cent fat. It is quite similar to corn in chemical composition and in feeding value. However, it is no more valuable than corn, and consequently should not be purchased unless it is cheaper than corn. It is especially valuable for fattening animals and for milk cows, but its use is subject to the same limitations as that of corn.

WHEAT BY-PRODUCTS

Most of the wheat by-products come from the manufacture of flour for human consumption. The principal by-products used in stock feeding are bran, shorts, middlings, red dog flour, shipstuff, and wheat screenings.

When wheat first enters the flour mill, it is screened, separating out the broken and shrunken kernels, weed seed, dirt, and other impurities. The screenings are often sold on the market as stock feed under the name of wheat screen-

ings. The cleaned wheat then passes through a series of rollers and on to bolting cloth which bolts out the finer particles or flour. The residue, consisting of the coarser particles, is divided by bolting into bran, shorts, middlings, and red dog flour. Ordinarily from 25 to 33 per cent of the weight of the wheat remains in the form of these by-products.

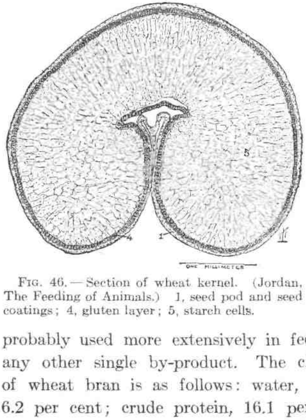

FIG. 46. — Section of wheat kernel. (Jordan, The Feeding of Animals.) 1, seed pod and seed coatings; 4, gluten layer; 5, starch cells.

Bran consists of the three outer coats of the grain and the rich protein or aleurone layer just underneath. Sometimes screenings are mixed with the bran, which decreases its feeding value. Bran is probably used more extensively in feeding livestock than any other single by-product. The chemical composition of wheat bran is as follows: water, 10.0 per cent; ash, 6.2 per cent; crude protein, 16.1 per cent; crude fiber, 10.0 per cent; nitrogen-free extract, 53.3 per cent; and fat, 4.4 per cent. Its net energy value is 48.2 therms per 100 pounds. It is fairly high in protein, high in mineral matter, except lime, and fair in carbohydrates and fat. In general, its feeding value is much higher than its chemical analysis indicates. It has the requisite bulk necessary to make it feed well with such highly concentrated feeds as corn, and it

also has a slight laxative effect upon the animal which is much valued by feeders. It ordinarily is not used as the sole concentrate, but as a supplement to some more concentrated feed.

For Growing Stock. — Bran is an excellent supplementary feed for nearly all classes of growing stock. It should be remembered, however, that it is quite deficient in lime, which is essential to the proper growth of the bones. Henry and Morrison [1] state that horses heavily fed on bran sometimes suffer from a form of rickets, known to horsemen as "bran disease," which seriously affects their bones. Thus bran should be fed with feeds which are rich in lime, such as the legumes.

For calves and growing cattle, bran and ground corn in the proportion of two parts of the former to one of the latter make an excellent combination of concentrates if it is not too expensive. It also should be used when feeding heavy feeds, as barley or rye meal. Young cattle which are being wintered without the use of clover, alfalfa, or other legume hay will make good use of two or three pounds of bran per day. Because of its physical effect, bran is considered a very valuable addition to the ration of colts. As stated previously, it should be fed with feeds which are rich in lime. Bran is too bulky and fibrous to constitute a large part of the pig's ration. At present prices it is also entirely too expensive for this purpose. It may be used to advantage for young lambs if fed in small amounts. It is too bulky to be used as the major part of the concentrates.

For Fattening Stock. — As the chemical composition and the energy value indicate, bran is not a fattening feed. On

[1] "Feeds and Feeding," p. 157.

account of its beneficial physical effect, bran, if not too expensive, may form one-half of the concentrates for fattening cattle during the first stages of fattening, after which it should be gradually decreased until only a small amount, if any, is being used, on account of its bulk and high content of crude fiber. Bran is usually too expensive to use in the ration of fattening animals, especially if they have clover or alfalfa hay.

For Breeding Stock. — Both on account of its chemical composition and its physical effect, bran is adapted for use in the rations of all classes of breeding animals. Especially is this true when the ration is of a heavy, concentrated nature, or when no legume roughage is available.

For Milk Cows. — Bran, owing to the protein and mineral matter which it contains, its laxative nature, and the bulk which it imparts to the ration, is particularly well adapted for use in the ration of the dairy cow. With a non-nitrogenous roughage, bran may constitute one-half of the concentrates of the ration. With a nitrogenous roughage, such as clover or alfalfa hay, bran need not form over one-third the concentrates. Bran, ground oats, and ground corn in equal parts make a satisfactory ration unless too expensive, in which case the amount of bran and oats may be decreased and cottonseed meal or linseed meal added to furnish protein and mineral matter. Bran is regarded by many dairymen as an essential constitutent of the ration unless good alfalfa hay is available.

For Work Horses. — Bran is too bulky and contains too much crude fiber to be used in the ration of work horses except in small amounts. A bran mash seasoned with salt and ginger should be fed once or twice a week to horses at hard work in order to keep their bowels loose.

Shorts are the fine particles of the outer and inner bran separated from the coarse bran and the white, or flour middlings. The sweepings, dust, and ground weed seed of the flour mills are often added. Shorts are also known as "standard middlings," or "brown middlings."

The average chemical composition of shorts is as follows: water, 10.0 per cent; crude protein, 17.8 per cent; nitrogen-free extract, 55.9 per cent; crude fiber, 7.0 per cent; fat, 5.0 per cent; and mineral matter, 4.3 per cent.

Inasmuch as shorts and middlings are similar in feeding value, the discussion of the feeding value of middlings may be accepted as also applying to shorts, if one remembers that shorts are considerably lower in feeding value.

Middlings consist of the finer bran particles and some low grade flour. The amount of flour is the distinguishing difference between middlings and shorts, the former containing a much larger amount than the latter. Middlings are usually designated as "flour" middlings, or as "white" middlings, in order to distinguish them from standard middlings or shorts. Inasmuch as flour or white middlings contain more low grade flour and less bran and sweepings than shorts or standard middlings, they are considerably higher in feeding value and command a higher price on the market.

The chemical composition of flour middlings is as follows: water, 10.0 per cent; crude protein, 18.8 per cent; nitrogen-free extract, 59.9 per cent; crude fiber, 3.3 per cent; fat, 4.8 per cent; and mineral matter, 3.2 per cent.

Middlings have more starchy material, less crude fiber, a little more protein, and less mineral matter than bran. Like bran, they are deficient in calcium or lime. Their energy value is considerably greater than that of bran.

Middlings (and shorts) are preëminently a feed for hogs. When cheap enough, they may make up a large proportion of the rations of growing pigs and brood sows. With corn, they make a very satisfactory ration for fattening hogs, especially when they have access to pasture. Middlings may constitute from 25 to 50 per cent of the concentrates of such rations. An excess of middlings will tend to produce soft pork. Hogs, when fed large amounts of middlings, should have access to a mineral mixture to make up the deficiency of lime in the ration.

Middlings may be fed to cattle and sheep along with other concentrates, but usually other feeds are better for this purpose. Mixed with ground grain, they are often used for dairy cattle. They are not used for horse feeding to any great extent, and never should be used except in combination with other grain, as they tend to form a pasty mass in the stomach and cause colic.

Red dog flour is low-grade flour usually containing the wheat germ. It is rich in crude protein, carbohydrates, and fat. It is not as high in ash as bran or middlings. It is adapted especially for hog feeding, being considered by many stockmen as even superior to middlings for this purpose. Consequently, it usually sells for a higher price than middlings. It also may be used in about the same manner as middlings as a part of the rations of horses, dairy cows, and calves.

Until one has had some experience with shorts, middlings, and red dog flour, it is often quite difficult to distinguish one from the others. Perhaps the best way is to taste a little of the feed. Red dog flour immediately rubs up into a fine paste on the tongue. Flour middlings rub up into a

coarser paste, due to the ground bran in them. Shorts do not form a paste at all. After tasting all three of these feeds, one after the other, one usually has no trouble in distinguishing them.

Shipstuff is a mixture of all or any of the by-products obtained from the milling of the wheat berry. Its feeding value, of course, depends upon the products which enter into its composition. In some localities the term shipstuff is used to designate middlings or shorts.

Wheat screenings, as their name implies, consist of the broken and shrunken wheat kernels, weed seeds, and other foreign material which result from the cleaning and grading of wheat. Their feeding value, of course, depends largely upon the proportion of wheat to weed seeds and dirt. *Screenings should always be finely ground in order to prevent the introduction of weeds on the farm.* The screenings are often added to the bran and sold either as pure bran or as "bran with screenings." Screenings are used also to a considerable extent in many commercial mixed feeds.

BARLEY BY-PRODUCTS

The principal by-products of barley are obtained from the breweries. They are brewers' grains (wet and dry) and malt sprouts.

Brewers' Grains. — In the manufacture of beer, the barley grains are first soaked in warm water until they are soft. They are then held at a comparatively high temperature and allowed to sprout, during which process a considerable part of the starch of the grain is changed by the action of enzymes to maltose or malt sugar. After sprouting, the grains are quickly dried and the little rootlets are removed. These

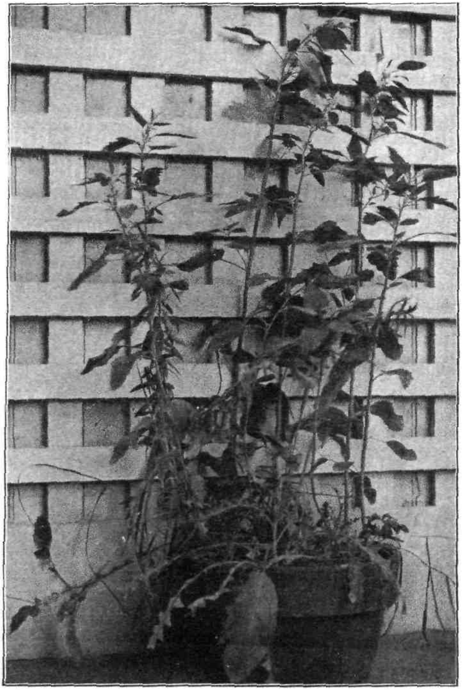

Fig. 47. — *Weeds growing from seed found in a commercial feed containing screenings.* (Vermont Experiment Station.)

constitute the feed, malt sprouts. The residue after the rootlets are removed is known as "malt." The malt is extracted with water to remove the soluble sugar which is used as a source of the alcohol of the beer. The freshly extracted malt is known as "wet brewers' grains." After drying they are called "dried brewers' grains." Brewers' grains are relatively higher in protein than barley.

Cattle of all ages relish brewers' grains. They rank high as a source of protein, containing 25.6 per cent. They may be fed in wet form if within a reasonable distance of the brewery and if care is taken to keep the feed-boxes tight and clean so that none may escape and spoil under the mangers. Unless proper sanitary measures are taken, however, the wet grains should not be used. Twenty to thirty pounds per day along with corn may be fed. Brewers' grains may be fed with profit to young growing cattle, but usually they cannot be fed profitably to fattening cattle unless they are very cheap. Sheep do not relish the wet grains.

In the dry form they rank along with such feeds as bran and linseed meal for dairy cows and they are no more perishable. Four or five pounds daily may be fed along with corn or corn meal. Instances have come to the notice of the author in which physicians have refused to indorse milk from dairies using dried brewers' grains. However, such prejudice is entirely unwarranted. Dried brewers' grains are nearly as satisfactory for horses as oats. One-third to one-half of the concentrates may consist of dried brewers' grains. On account of their high content of crude fiber, they are not suitable for hogs. The dried grains may be used in the ration of breeding ewes.

Malt sprouts are the dried rootlets obtained from the barley used for the manufacture of malt. They are not very palatable, but they contain a considerable amount of crude protein, — 26 per cent, a large proportion of which is in the form of non-protein. They may be fed in moderate quantities, 2 or 3 pounds per day, to milch cows. They also may be used in limited quantities in the rations of other farm animals. They usually are soaked in water several hours before feeding. They should always be fed with more palatable feeds.

MISCELLANEOUS CEREAL BY-PRODUCTS

Oats By-products. — The principal by-products of oats are shorts, middlings, and hulls, from the oatmeal and breakfast food factories, and oat clippings, obtained in the manufacture of clipped oats.

Oat shorts consist of the seed coats of the oat grain lying immediately inside the hull, being a fuzzy material carrying with it considerable portions of the fine, floury part of the groat (*i.e.* the hulless oat berry) obtained in the milling of rolled oats.

Oat middlings are the floury portions of the oat groat obtained in the milling of rolled oats. Oat shorts and middlings are quite valuable as feeds when obtainable. They may be used in the same manner as wheat shorts and middlings.

Oat hulls, although not a concentrate, can best be discussed here. The hulls are the outer chaffy coverings of the oat grains. They are quite low in digestible nutrients and are no more valuable for feeding than so much straw. Oat hulls and corn are often ground together and sold as

"corn and oat feed." They are also used in many mixed and patent feeds. It is often very difficult to distinguish between ground oats and ground oat hulls when mixed with other ground feeds. Consequently, the farmer should exercise great care in purchasing feeds of this kind.

Oat dust consists of the minute, hairlike particles which adhere to the end of the hulless oat kernel. It is usually used as a constituent of commercial mixed feeds. It ranks between oat middlings and oat hulls in feeding value.

Oat clippings or *clipped oat by-product* are the light, chaffy material broken from the ends of the hulls in the process of clipping, together with hulls, light, immature oats, and dust. Their feeding value is very low and they are often used as an adulterant of other feeds, and as a constituent of many mixed commercial feeds, especially molasses feeds.

Rye By-products. — The principal by-products from rye are bran, shorts, and middlings, obtained in the manufacture of rye flour, and distillers' slops and grains, obtained in the manufacture of whisky and grain alcohol.

Bran, Shorts, and Middlings. — In origin and chemical composition, rye bran, shorts, and middlings closely resemble the corresponding by-products of wheat. However, in feeding value they are much inferior. If fed in large quantities to milch cows, they affect the flavor of the product. Rye shorts or middlings when fed to hogs produce a soft, inferior quality of pork. The quantity of these by-products available is small, owing to the small amount of rye bread used. Their use is becoming more and more general, however. In parts of Europe they occupy an important place as stock feeds. If used they should be purchased

considerably more cheaply than the corresponding wheat by-products.

Rye feed. — Rye bran, shorts, and middlings are often mixed together and marketed as rye feed.

Distillers' grains from rye are much inferior to those from corn. However, most of the grains on the market consist largely of corn. The feed should bear the name of the cereal predominating.

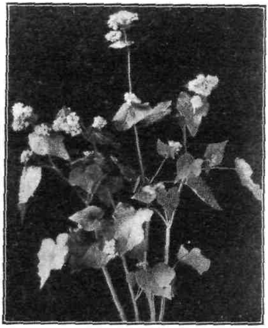

FIG. 48. — Buckwheat in bloom. (Livingston, Field Crop Production.)

Rice By-products. — The rice by-products are of considerable importance in the South, but of little importance in the corn-belt.

Rice hulls are the outer chaffy coverings of the rice grain. Their feeding value is not only very low but they are dangerous to the animal, as they irritate the walls of the digestive tract. They are sometimes used in mixed commercial feeds.

Rice bran is the cuticle beneath the hull. It soon becomes rancid and unpalatable, but is a good feed for cattle and horses when not rancid.

Rice polish is the finely powdered material obtained in polishing the kernel. It has a feeding value about equal to corn.

Buckwheat By-products.[1] — The by-products of buckwheat are shorts and middlings, obtained in the manufacture of buckwheat flour. They are that portion of the buckwheat grain immediately inside of the hull after separation from the flour. They are considerably higher in protein than wheat shorts and middlings. They are valuable feeds, especially for dairy cows and hogs. Care should be taken that the ground hulls, which are worthless, are not mixed with them. The ground hulls are sometimes mixed with the middlings and sold as buckwheat bran or feed.

[1] Although buckwheat is not a cereal botanically, it is usually classed as such for commercial purposes.

CHAPTER XI

THE OIL BY-PRODUCTS

THE oil by-products are the residues from the oil-bearing seeds after the removal of the oil. The principal oil by-products in this country are obtained from flaxseed and cottonseed. Of minor importance are soybean cake, sesame cake, peanut cake, sunflower-seed cake, rape-seed cake, coconut cake, and corn-germ cake. Most of these latter are of more importance in Europe.

FLAXSEED BY-PRODUCTS

The by-products of flaxseed are "old process" linseed oil cake or meal, "new process" linseed oil meal, flax feed, flax plant by-product, and unscreened flax oil feed.

Linseed oil cake or meal often is spoken of as simply oil cake or meal, or linseed cake or meal. Two methods are used in obtaining the oil from flaxseed. In the first, or "old process" method the seeds are crushed, heated with steam, and the oil removed by subjecting the crushed seeds to an enormous pressure. After the removal of the oil by the pressure process, the residue is a hard, board-like cake about 1 inch thick, 1 foot wide, and three feet long. It may be sold in this form as old process linseed cake or, as is more often the case, it may be ground to a meal of varying degrees of fineness and sold as old process linseed meal. It is

advisable to buy it in nut or pea sizes, as when sold in the form of a fine meal it is easily adulterated with flax screenings and when sold in the cake it is difficult to break up for feeding, without the use of a power grinder.

In the second, or "new process," method the flaxseed is crushed, heated with steam, and placed in large percolators. It is then treated with naphtha, which dissolves out the oil. It is again treated with steam to drive out the naphtha. It is then dried, sacked, and marketed as new process linseed meal. The first method is most commonly used in this country. Consequently, most of the linseed meal on the American market is old process. The extraction method removes the oil more thoroughly than the other method.

The average chemical composition of old process linseed meal is as follows: water, 8.5 per cent; ash, 5.2 per cent; crude protein, 34.3 per cent; crude fiber, 8.5 per cent; nitrogen-free extract, 36.4 per cent; and fat, 7.1 per cent. The net energy value is 78.9 therms per 100 pounds. New process linseed meal is higher in protein, but contains only a small amount of fat. Although there is more protein in new process linseed meal, there is but little more of it digestible than in the old process meal. The greater amount of fat in the old process meal makes it more valuable than the new process meal for feeding purposes.

Linseed cake or meal is one of the most valuable and useful by-products. It is not only very high in feeding value but, unlike cottonseed cake or meal, it is a safe and usually a profitable feed with any kind of animals. In addition to its high feeding value, it is very appetizing, has a slightly laxative effect, and imparts to the hair of the animals a glossy look indicative of thrift. As its chemical composition

indicates, linseed meal should not be used as the sole concentrate of the ration, but in connection with less nitrogenous concentrates.

For Growing Stock. — Linseed meal is one of the best supplementary concentrates for growing animals, both on account of its high feeding value and its physical effect. It is a very important addition to the ration of the skim-milk calf. For growing cattle, it may form as much as ten per cent of the concentrates of the ration when not too expensive. It is also very good for colts and may be substituted for a part of the oats in the ration. It is usually fed to secure finish and bloom in fitting horses for show or sale. It may be fed in amounts up to one pound per day. Oil meal may be used for pigs, but other nitrogenous supplements, as middlings and tankage, usually are preferred. It is excellent in the ration of young lambs, both before and after weaning.

For Fattening Stock. — For fattening steers, two or three pounds per day can be given to advantage. It is often fed near the close of the feeding period, on account of its beneficial effect upon the appetite, digestion, and finish of the animal. It is used quite extensively with show cattle. For fattening hogs, linseed meal may be fed in small quantities, approximating 10 to 20 per cent of the concentrates to good advantage. Large quantities seem to affect the appetite of the hog adversely. Usually tankage or middlings is preferred. For fattening lambs and sheep, it may be used to advantage up to one-third of a pound per day unless the ration consists of corn and clover or alfalfa hay, in which case its use is not profitable.

For Breeding Stock. — Linseed meal is one of the best nitrogenous supplements for breeding animals of all classes.

Its laxative effect and high protein content make it valuable for this class of animals.

For Milch Cows. — Up to three pounds per day, linseed meal will improve almost any dairy ration. An excess of linseed meal may affect the quality of the butter, as it tends to produce a soft butter.

For Work Horses. — One-half to one pound may be fed to advantage to horses. McCampbell at the Kansas Experiment Station[1] found that one pound of linseed meal was equivalent to four pounds of bran when fed with corn, oats, and prairie hay. It is not necessary, however, when they are on pasture. This feed gives the horse a gloss and sleekness of coat which materially improves the appearance. It is very good to restore overworked or overfed horses to good condition. Some horses cannot use it, as it scours them too much.

Flax feed or screenings consist of a variable mixture of inferior flaxseed, weed seeds, stalks, leaves, dirt, etc. Like all screenings, it should be finely ground to destroy the viability of the weed seeds present. It is not recommended at the prices usually asked for it. It is often used as a constituent of mixed commercial feeds, and is sometimes sold under fancy trade names, as "flax flakes," "linomeal," etc.

Flax plant by-product consists of flax pods, inferior flax seeds, and portions of the stem. It is usually used in mixed commercial feeds, although it is sometimes sold as "flax bran." Its feeding value is quite low.

Unscreened flax oil feed is the by-product resulting from the extraction of the oil from unscreened flaxseed. It is lower in feeding value than oil meal from the screened seed.

[1] Bul. 186.

COTTONSEED BY-PRODUCTS

The principal cottonseed by-products are cottonseed cake or meal, cold pressed cottonseed, cottonseed feed, cottonseed hulls, and cottonseed hull bran.

Cottonseed Cake, or Meal. — Cottonseed cake is the residue remaining after most of the hulls and lint have been removed and the cottonseed have been crushed, heated, and the oil pressed out in a manner similar to the manufacture of old process linseed meal previously described. Cottonseed meal is the finely ground cake, although it is sometimes sold in the pea or nut size, especially in the West or where it is fed in the open and liable to be blown away by the wind.

Cottonseed meal should be a light yellow in color. A dark color indicates the presence of ground hulls which often are used as an adulterant. This adulteration may be detected definitely by putting a small quantity of the meal in a glass tumbler, pouring hot water over it, quickly stirring, allowing it to settle for a few seconds, and then pouring off the unsettled portion. If the residue is darker in color than the untreated meal, ground hulls are present. If successive treatments intensify the dark color, the adulteration is proportionate. Wet, musty, or moldy meal should never be used under any conditions.

The average chemical composition of cottonseed meal is as follows: water, 7.0 per cent; ash, 6.7 per cent; crude protein, 44.6 per cent; crude fiber, 6.5 per cent; nitrogen-free extract, 25.2 per cent; and fat, 10.0 per cent. Its net energy value is 84.2 therms per 100 pounds. It is one of the richest feeds in protein and energy. It is also high in fat and ash. Cottonseed meal should be purchased on the

basis of its protein content. There are three grades of it on the market, viz., choice, prime, and good. Choice cottonseed meal contains 41 per cent or more of protein; prime contains 38.6 to 41 per cent; and good contains 36 to 38.6 per cent. Cottonseed meal should not contain less than 36 per cent protein; if it does, it is adulterated.

Unlike linseed meal, cottonseed meal is not a safe feed to use with impunity for all classes of stock. If fed with discretion, however, it often makes a most profitable addition to the ration. If fed in large amounts for long periods, cottonseed meal may act as a poison to the animal and, in many cases, cause death. It is particularly fatal to hogs. The nature of the poisonous principle has not yet been determined. It also has a costive action. Although its use may prove disastrous if fed carelessly, there is no reason why the careful feeder should not make use of this highly nutritious feed.

For Growing Animals. — Although high in protein and mineral matter so essential to satisfactory growth, the general use of cottonseed meal is not recommended for this class of farm animals. It should not be used for calves or pigs. For young growing cattle, two or three pounds per day when not on pasture will promote growth. It is not advisable to use it in the rations of colts or lambs, although it is so used sometimes.

For Fattening Animals. — Cottonseed meal is a very good nitrogenous supplement for fattening cattle. On account of its costive effect and high protein content, it makes an admirable addition to a ration which contains corn and corn silage. It may be used up to four or five pounds per day; in the South, much larger quantities are often fed,

but in the corn-belt, it is not desirable to feed such large amounts unless corn is very expensive.

As previously noted, hogs are especially susceptible to the poison of cottonseed meal. Although it can be fed to them without disastrous results, it is not advisable for the inexperienced feeder of the corn-belt to attempt to learn how, as it may prove a costly experience with the results not worth the risk. Recent experiments indicate that cottonseed meal if fed with copperas may be used by hogs with safety. However, this has not been proven definitely. There is no danger in hogs following steers which receive cottonseed meal in their ration.

Cottonseed meal may be used in the rations of fattening lambs and sheep, especially if they are fed a non-nitrogenous roughage. It is not as satisfactory, however, as linseed meal.

For Breeding Stock. — Although used for breeding stock to a certain extent, the author would not advise its extensive use for this class of animals. Especially is this true in the case of pregnant animals. When suckling their young its use may be permitted to a certain extent.

For Milk Cows. — In moderate amounts, cottonseed meal is a very satisfactory addition to the ration of dairy cows. Not over three or four pounds daily should be fed, as more not only may derange the digestive system, but will produce a hard, tallowy, poorly flavored butter.

For Work Horses. — Gay [1] states that cottonseed meal is now generally recommended as a complete or partial substitute for oats, in combination with corn, to cheapen the ration. Cochel, at the Pennsylvania Experiment Station,[2]

[1] "Productive Horse Husbandry," p. 237. [2] Bul. 117.

after feeding as much as three pounds of cottonseed meal per day to fattening draft horses, concluded that using cottonseed meal to replace oats resulted in a cheaper ration, a larger gain, more economical gains, and a higher finish. Kennedy, Robbins, and Kildee, at the Iowa Experiment Station,[1] after comparing corn and linseed meal with corn and cottonseed meal for work horses, concluded that cottonseed meal gave somewhat better results than linseed meal. The use of either resulted in a substantial lowering of the cost of maintaining the horses.

Cold pressed cottonseed is the product obtained by subjecting the unheated, undecorticated seed (*i.e.* the unhulled seed) to enormous pressure to remove the oil. It includes the entire cottonseed, less the lint and oil removed. It may be sold in large thin flakes, or it may be ground to a meal. It has a lower feeding value than cottonseed meal as it contains much more hulls and lint. It contains about 27 per cent of protein. It may be used in about the same ways as cottonseed meal. It is sometimes sold as "caddo cake."

Cottonseed feed is a mixture of cottonseed meal and ground cottonseed hulls, containing less than 36 per cent of protein. Its feeding value depends upon the proportion of cottonseed meal in it as indicated by its per cent of protein. Usually, cottonseed feed contains about 23 per cent of protein. Consequently, the feeder could not afford to pay for it more than one half the value of choice cottonseed meal. As a matter of fact, it ordinarily sells for only a few dollars per ton less than choice cottonseed meal. In general it will be more economical for the corn-belt farmer

[1] Bul. 109.

to buy the better grades of cottonseed meal at a higher price, rather than pay the freight on the hulls, which have little value as a feed.

Cottonseed hulls are an important by-product in the South, where they are used as a roughage. They are little fed in the corn-belt except as they are used as an adulterant of cottonseed meal. They often may be used economically as a part of the roughage of the ration when hay is very expensive. Their feeding value is somewhat less than that of straw.

Cottonseed hull bran consists of the hulls, free from lint and finely ground. The feeding value is about the same as that of ordinary cottonseed hulls.

MISCELLANEOUS OIL BY-PRODUCTS

Peanut cake, or meal is the residue after the extraction of the oil from the peanut. Inasmuch as it contains about 48 per cent of crude protein when hulled, it is very valuable as a nitrogenous supplement. It is used little in this country, but is used extensively in Europe.

Soybean cake, or meal is the residue after the extraction of the oil from soybeans. It contains about 43 per cent of protein and is as valuable for feeding as cottonseed meal. It is imported from China and Japan and used to a considerable extent along the Pacific coast, particularly as a feed for dairy cows and for poultry, although it may be used for the other farm animals. It is not used to any extent in the East and Middle West.

Coconut cake, or meal is the residue remaining after extraction of the oil from the dried meat of the coconut. It is used some in the East but more extensively on the Pacific

coast. It contains 20 per cent or more of protein. It is a very palatable feed and, if cheap enough in price, may be used for all classes of farm animals. It is especially recommended for dairy cows, as it produces a fine butter of considerable firmness. It has the disadvantage of becoming rancid in a short time in warm weather.

Sunflower seed cake is the residue remaining after extraction of the oil from the sunflower seed. It is used mostly in Russia. It contains about 39 per cent of protein.

Rape seed cake is the residue remaining after extraction of the oil from rape seed. It is quite high in protein, 33 per cent.

Sesame seed cake is the residue after extraction of the oil from the sesame seed. Like the other oil by-products it is high in protein, 40 per cent.

Corn oil meal, or germ meal has already been discussed under "Corn By-products."

Peanut hulls are sometimes ground and sold as "peanut bran," or used as a constituent of mixed commercial feeds. Their feeding value is lower than that of straw.

CHAPTER XII

THE PACKINGHOUSE BY-PRODUCTS

THE packinghouse by-products produced in the big slaughter houses, which are of use for feeding purposes, consist of blood, bone, and meat scraps. These are worked into various forms, but those of the most importance to the stock feeder are tankage or meat meal, dried blood (blood meal, blood flour, etc.), meat scraps, cracklings, and ground bone or bone meal.

Tankage and meat meal are the same thing. Some manufacturers, who are equipped to make up a special meat product of this character for feeding purposes, market their product under one name and some under another. In the main essentials there is no difference between tankage, which for feeding purposes usually is designated as "Digester Tankage," and meat meal. In fact, some firms sell it as "Meat Meal Digester Tankage."

A proper feeding tankage is made from meat trimmings, which are thoroughly cooked for several hours in pressure tanks under 50 to 60 pounds live steam pressure. This cooking, together with a subsequent pressing of the material, removes the principal part of the grease, after which the residue is thoroughly dried under high heat in dryers especially designed for that purpose. After being dried, this selected material is ground and screened over special equipment designed to put it in the best possible mechanical condition

for feeding purposes. Of course, the high heat to which tankage is subjected both during cooking and drying sterilizes it completely. Thus, there is no danger of transmitting disease to a healthy animal through feeding properly prepared tankage, or meat meal. No condemned carcasses are used in the manufacture of the higher grades of these feeds, although they are often used in the lower grades which are usually used for fertilizer. Sometimes the lower grades are sold for feeding purposes. Their use, however, is not advisable. Peat and hair are sometimes used to adulterate the lower grades of tankage.

Tankage usually is sold on a guarantee that the protein content will be not less than 60 per cent, which, of course, is equivalent to 1200 pounds of protein per ton. Some tankages are sold on a 50 per cent guarantee, likewise on a 40 per cent guarantee, but the more highly concentrated goods are to be recommended, inasmuch as the expenses per ton for preparation, bagging, shipping, and hauling to the farm are the same in the case of a 40 per cent protein tankage as in the case of a 60 per cent protein tankage. Consequently the more highly concentrated goods figure much lower per unit of protein delivered on the farm. In addition to the protein, these feeding tankages also contain about 10 per cent of fat, from 10 to15 per cent of phosphates, and about 7 per cent of carbohydrates. These supplementary constituents are very important, but as a feeding tankage is bought principally on account of its protein value, proper consideration should be given to the amount of protein and the quality of that protein when purchasing a tankage for feeding purposes. Particular attention should be given to the percentage of crude fiber, as this is quite variable. If tankage contains much over 6 per

cent of crude fiber, it is an indication that it has been adulterated with peat.

The principal use of tankage and meat meal is as a supplement to corn for growing and fattening hogs. It not only supplies the protein, but also the mineral matter in which corn is deficient. Furthermore the protein of tankage is especially rich in the amino acids in which corn is deficient. For supplementing corn it is usually cheaper per pound of protein and also more efficient than middlings or oil meal. Usually it is not profitable to feed more than 10 per cent of tankage in the ration. The amount fed should depend upon the amount of protein in the tankage, and upon the protein requirement of the hogs. Tankage and meat meal are more valuable adjuncts to the corn ration when the hogs are fed in dry lot than when they have access to pasture. It should be carefully mixed with the other feed to get an equal distribution so that all the animals in the feed lot will get an equal amount. Tankage will keep indefinitely if it is stored in a dry place. It may spoil if allowed to soak in the slop too long.

In Europe, meat meal is sometimes fed in small quantities to horses, cattle, and sheep. It has not been used in this country to any extent for animals other than hogs.

Blood meal, or dried blood is blood from slaughtered animals, dried and cooked. It is the highest in protein of any feedingstuff, containing about 85 per cent. It is quite low in mineral matter as compared with tankage. It is used principally for pigs as a supplement to corn. Such animals should have free access to some mineral mixture. Pigs at 3 months old may be given a tablespoonful daily and younger pigs in proportion, although tankage is usually

more economical for hog feeding, as blood meal is quite expensive. A teaspoonful may be fed in the milk of the skim milk calf at weaning and this amount gradually increased. It will have a tendency to prevent scours. It also has been fed to lambs.

Blood flour is finely ground blood meal. There is no difference in chemical composition or in feeding value, although blood flour usually sells for more on the market.

Meat scraps consist largely of beef trimmings which are cooked in large open vats in the presence of grease for the purpose of liberating all the grease possible. The resulting cracklings are then subjected to heavy pressure to remove the grease and water. The cakes are then ground and bagged. Meat scraps contain about 50 per cent protein. They are used for poultry feeding.

Cracklings are the residues left from the manufacture of lard and tallow. Although they are not regularly listed on the market as a feedingstuff, they often may be obtained from local slaughter houses at a low price. They are as high in crude protein as tankage and contain considerably more fat. Digestion experiments by Dietrich and Grindley at the Illinois Experiment Station [1] showed that cracklings were considerably more digestible than tankage. For hogs, good cracklings should be at least as valuable as tankage. They are also very good for poultry.

Raw bone meal, as the name implies, consists of ground bone. It is made from clean, sound bones from healthy animals. It is high in protein and very high in ash. It is used especially for hogs and poultry to furnish additional mineral matter to the ration. A little may be given to other

[1] Bul. 170.

classes of farm animals if they show a craving for mineral matter.

A distinction should be made between raw bone meal, which is used for feeding purposes, and steamed bone, which is used for fertilizer. Junk bones and bones from condemned animals are often used in the manufacture of bone meal for fertilizer. Also they are steamed to remove the protein substances which are made up into glue. Thus there is no comparison between the two for feeding purposes.

CHAPTER XIII

MISCELLANEOUS CONCENTRATES

UNDER the head of miscellaneous concentrates may be classed proprietary or patent preparations, commercial mixed feeds, and such other concentrates as do not logically fall into any of the other classes as previously discussed.

Proprietary preparations, or patent "stockfoods," as they are often called, vary in constitution from concentrated medicines to bulky feed with corn meal, screenings, bran, linseed meal, cottonseed meal, ground corn cobs, oat hulls, peat, etc., as their chief constituents. They also usually contain salt, spices, and drugs, which impart a more or less desirable odor and flavor to the product. The most unwarranted claims are often made by the manufacturers for their products and, through judicious advertising in the farm papers, enormous quantities are sold at prices far above the true value of the product. There are few farmers who have not used patent stockfoods at some time or other. It is claimed by many manufacturers that the use of their "food" will increase the digestibility of the ration, decrease the cost of gains, prevent and cure disease, etc. As a matter of fact, however, practically all experiments are unanimous in the conclusion that patent stockfoods do not increase the digestibility but, on the other hand, sometimes decrease it; they increase the cost of gains; and they usually have no effect upon the health of the animal. The actual

feeding value of such preparations is certainly no greater than a mixture of corn meal, oat hulls, linseed meal, or whatever feedingstuffs make up the stockfood. Inasmuch as the price of such preparations is usually from $100 to $125 per ton, it is evident that when it comes to buying commercial feeds, the farmer should invest in bran, linseed meal, middlings, or some other standard product in which he is much more liable to get the worth of his money. Stockfoods may act as a stimulant to the appetite, but animals which are properly managed do not need stimulants to their appetites. For the man who thinks he must have a stimulant or tonic in the ration, the Iowa Station [1] recommends the following prescription:

powdered gentian	1 lb.
powdered ginger	1 lb.
fenugreek	5 lb.
common salt	10 lb.
bran	50 lb.
linseed meal	50 lb.

Hills, Jones, and Hollister at the Vermont Station [2] recommend the following:

ground gentian	1 lb.
ground ginger	¼ lb.
powdered saltpeter	¼ lb.
powdered iron sulphate	¼ lb.

Mix and give one tablespoonful in the feed every day for ten days; omit for three days, and then feed daily for ten days.

[1] Bul. 87. [2] Bul. 104.

The following mixture is also recommended by the Vermont Station:

fenugreek	$\frac{1}{2}$ lb.
ginger	$\frac{1}{2}$ lb.
powdered gentian	$\frac{1}{2}$ lb.
powdered sulphur	$\frac{1}{2}$ lb.
potassium nitrate	$\frac{1}{2}$ lb.
resin	$\frac{1}{2}$ lb.
cayenne pepper	$\frac{1}{4}$ lb.
ground flaxseed	3 lb.
powdered charcoal	$1\frac{1}{2}$ lb.
common salt	$1\frac{1}{2}$ lb.
wheat bran	6 lb.

The farmer, with the aid of a druggist, may prepare any of these much more cheaply than he can buy such preparations on the market.

There are a few patent medicines on the market which have some value, but the farmer should use much judgment in buying them, as many are practically worthless. If an animal is sick or needs "conditioning," one should have a competent veterinarian prescribe for it, rather than give it a "cure-all" which, as likely as not, consists principally of ground oat hulls, corn cobs, ginger, pepper, and epsom salts.

Commercial Mixed Feeds. — There are mixed, prepared, or "balanced" feeds on the market without number. In many cases, these "balanced" feeds consist of mixtures of standard feedingstuffs, such as ground corn, ground oats, gluten feed, middlings, linseed meal, etc. However, often times these mixtures are composed of ground corn cobs, corn bran, oat hulls, oat clippings, screenings, and other products

low in feeding value. Thus such feeds should be purchased only on a guaranteed analysis either from the manufacturer or from the state authority having in charge the regulation and inspection of commercial feedingstuffs. Many states now have laws *requiring that the minimum percentages of* crude protein and fat, and the maximum percentage of crude fiber be printed on the container, or on an attached label. If the feed is sold in bulk the dealer is usually required to furnish a guaranteed analysis from the state authorities. Many *states require also that the ingredients making up the feed be* printed on the bag or label. Thus wheat bran which contains ground screenings must be designated as "bran with screenings." Having the chemical analysis of the feed, the purchaser should compare it with the average chemical analysis of similar feeds as given in Table 28. If the feed in question is much lower in crude protein and higher in crude fiber than the average, it indicates that the feed is low-grade or adulterated.

The Texas Experiment Station [1] suggests that the following standards be followed in buying commercial feedingstuffs:

Name of Feedstuff	Crude Protein not less than Per Cent	Crude Fat not less than Per Cent	Nitrogen-Free Extract not less than Per Cent	Crude Fiber not more than Per Cent
Alfalfa Meal	13.50	1.50	36.00	30.00
Barley Chops	11.00	1.50	65.00	6.00
Beet Molasses	9.00		59.00	
Beet Pulp	0.75		6.00	2.50
Blood, dried	84.00	2.50		
Brewers' Grain, dried	24.00	6.00	40.00	18.00
Corn Bran	9.00	5.00	63.00	10.00
Corn Chops	9.50	3.50	70.00	3.00

[1] Bul. 177.

Name of Feedstuff	Crude Protein not less than Per Cent	Crude Fat not less than Per Cent	Nitrogen-Free Extract not less than Per Cent	Crude Fiber not more than Per Cent
Corn Cob	2.00	.50	54.00	31.00
Corn Feed Meal	9.00	4.00	67.00	4.00
Corn, Ear Chops	8.00	3.00	64.00	7.50
Corn, Ear Chops with Shuck	7.75	2.75	62.00	10.00
Corn Germ Meal	10.00	3.50	66.00	5.00
Cottonseed Cake	44.00	7.50	24.00	8.50
Cottonseed Chops	23.00	20.00	25.00	18.00
Cottonseed, cold pressed	26.00	7.00	28.00	26.00
Cottonseed, cold pressed (ground)	26.00	7.00	.28.00	26.00
Cottonseed Hulls	3.00	.25	28.00	51.00
Cottonseed Meal	44.00	7.50	24.00	8.50
Feterita Chops	11.00	2.50	69.00	3.00
Feterita Head Chops	10.00	2.50	64.00	8.50
Hominy Feed	9.00	6.00	60.00	7.00
Kafir Chops	10.50	2.75	69.50	3.00
Kafir Head Chops	9.50	2.50	65.00	8.00
Linseed Meal, new process	33.00	3.00	38.00	10.00
Linseed Meal, old process	32.00	7.50	35.00	9.00
Meat Scraps	65.00	13.00	2.50	3.00
Meat Meal	65.00	13.00	2.50	3.00
Millet Seed	11.00	4.00	57.00	10.00
Milo Chops	10.00	2.50	71.00	3.00
Milo Head Chops	9.75	2.40	65.00	7.50
Molasses, blackstrap	2.40		65.00	
Oats, ground	11.00	4.00	58.00	10.00
Oat Hulls	3.00	1.00	51.00	30.00
Peanut Cake, cold pressed	30.00	10.00	23.00	23.00
Peanut Meal	44.00	7.50	23.00	7.50
Rice Bran	12.00	11.00	42.00	12.00
Rice Polish	12.00	7.00	60.00	3.50
Rice, ground rough	7.00	1.75	63.00	10.00
Rice Hulls	3.00	.50	37.00	36.00
Rye Chops	10.00	1.50	72.00	2.00
Sorgo Chops	9.50	3.00	69.00	3.00
Sunflower Seed	16.00	21.00	21.00	30.00
Wheat Bran	15.00	3.50	54.00	9.00
Wheat Chops	15.00	2.00	65.00	3.50
Wheat Mixed Feed	16.00	3.60	55.00	8.00
Wheat Shorts, standard	17.00	3.80	60.00	4.50

All buyers of commercial feedingstuffs should familiarize themselves with their state laws relative to the sale of commercial feedingstuffs and make good use of the bulletins, etc., published by the state authorities having the regulation in charge.

Even if the " balanced " mixed feeds offered by the dealer are composed of pure, sound feeds it is usually not profitable to buy them. Carbohydrates can be raised more cheaply on the corn-belt farms than any other place in the United States. What the corn-belt feeder lacks is protein, and when he buys any considerable amount of carbohydrates as he does when buying a balanced mixed feed, he buys a nutrient of which he already has an abundant supply in his farm feeds. Also he pays the freight both ways, the elevator man's profit, the commission man's profit, the manufacturer's profit, and the dealer's profit.

So, under ordinary conditions, corn-belt feeders should buy *only nitrogenous feeds, should insist on having a standard product, and should ask for the guaranteed analysis* of the feed.

Oftentimes there are different grades of the same feeds on the market. Thus one may purchase cottonseed meal containing 20 to 45 per cent of protein, or tankage containing 30 to 60 per cent of protein. Almost invariably it is more economical to purchase the best grades rather than the poorer ones, as it will not be profitable to pay freight on a lot of cottonseed hulls or peat.

In most cases it will pay the farmer to buy standard feedingstuffs and mix his own rations, as he usually can mix them as cheaply as the manufacturer, besides having the assurance of knowing exactly for what he is paying.

Molasses. — There are three kinds of low-grade molasses which are used for stockfeeding, beet molasses, cane molasses, and corn molasses.

Beet molasses is a by-product from the manufacture of sugar from sugar beets. It contains about 60 per cent of carbohydrates, largely in the form of sugar. Used in small amounts it is about three-fourths as valuable for feeding as corn. In large amounts it is very laxative or even purgative. Not over a few pounds should be fed daily. Beet molasses is not especially palatable, but has a bitter, alkaline taste. It is usually diluted with water and sprinkled over other feeds. Beet molasses is largely used in the manufacture of "molasses feeds."

Cane molasses or blackstrap is a by-product from the manufacture of sugar from sugar cane. It is a thick, black molasses, which has a pleasant odor and a sweet taste. It is very palatable, much relished, and is higher in feeding value than beet molasses. Like corn, it is high in carbohydrates and low in protein. It may be used for all classes of farm animals. In the North, it is usually used as an appetizer, or it is diluted with water and sprinkled over unpalatable and inferior feeds in order to increase their consumption. Not over 3 pounds per day should be fed to horses, fattening cattle, and milch cows. It may be fed to hogs in their slop. Unlike beet molasses, it is costive in action. It is used extensively in molasses feeds.

Corn molasses is obtained in the manufacture of corn sugar just in the same way that beet and cane molasses are obtained in the manufacture of beet and cane sugar. It contains only about 20 per cent of water. In feeding it should be at least as valuable as cane molasses.

Molasses Feeds. — Different feedingstuffs are often sweetened with molasses, dried, and sold under various trade names. Although some of these mixtures are good, often the molasses is used with material such as ground alfalfa or clover chaff, oat dust, oat clippings, screenings, peanut hulls, and other substances which have little or no feeding value. The use of molasses provides one of the best means possible for disguising substances which are low in nutritive value. It has been found that mixing beet molasses with peat or sphagnum moss greatly improves the palatability and neutralizes the alkalinity of the molasses. However, the peat does not add anything to the nutritive value, although it is quite high in nitrogen, because it is practically indigestible.

Usually the farmer cannot afford to buy such feeds at the high prices ordinarily asked for them. In general, it will pay the farmer to prepare his molasses mixtures at home, thereby utilizing the waste roughages of the farm, and not paying a fancy price for another man's low-grade roughage.

Beet pulp is a by product of the beet sugar factories. It is the residue after the extraction of a large part of the sugar of the beet. In the wet form, it consists of about 90 per cent water. In regions where it can be obtained cheaply, it may be fed with profit in either the wet or dry form to dairy cows, fattening steers, or fattening sheep. Souring does not decrease the value of the wet pulp. In fact, it is better relished this way. The dried beet pulp is only a little below corn meal in nutritive value. It is especially valuable for dairy cows and fattening cattle when properly supplemented by nitrogenous concentrates. However, it should not be used unless cheaper than corn. When fed to dairy

cows it is best to soak it in two or three times its weight of water, thereby providing a valuable succulent feed. It is often sweetened with molasses and sold under various trade names.

Salvage grain is grain which has been damaged in warehouse fires by fire, smoke, or water. It may consist of practically any grain, or it may be made up of a mixture of various grains. It sometimes contains considerable weed seed. In general, salvage grain has a fairly high feeding value for all classes of farm animals, though it depends largely upon the grains entering into its composition, and upon the extent of the damage by fire and water. Occasionally such feeds are made available to the farmer by local elevator fires at a very low price and, in such cases, he should make use of them. It usually will not pay him to buy salvage on the market, as the price is often as much as the price of the undamaged grain.

Skim milk is relatively high in protein and mineral matter. It is preëminently a feed for hogs. For young pigs it is probably the best supplementary feed. It is also good as a supplement to corn for fattening hogs. However, too much skim milk should not be fed. Weanling pigs should be started out on not more than 3 pounds of skim milk per pound of dry concentrates fed. Later the milk should be reduced to 2 pounds per pound of dry concentrates. When properly combined with concentrates, 5 to 6 pounds of skim milk are equal in feeding value to 1 pound of corn. Sweet milk is no better than sour milk, except that the former is preferable in the case of young pigs. Skim milk may be used also for calves if carefully fed and properly supplemented.

Buttermilk has about the same composition and the same feeding value for pigs as skim milk. If allowed to ferment in dirty tanks it may be dangerous.

Whey has about half the feeding value for hogs as skim milk.

Cocoa shells are the hard, outside coating or bran of the cocoa bean. They are dark brown in appearance and brittle in texture. They contain about 15 per cent of protein and about the same amount of crude fiber. In Europe they are used in the rations of horses and cattle and as an adulterant for oil cakes. They are just beginning to be used as a feed in this country. Lindsey[1] rates them as having not more than one-half the feeding value of corn meal. He states that they are best suited for use in the ration of dairy cows. They should be ground and 1 to 3 pounds daily should be fed.

Tin Plate By-product. — In the manufacture of tin plate after the plate has been put through the tin bath it goes into a bath of palm oil, then it is taken out and the excess oil is removed by means of wheat middlings, which are used over and over again to absorb the oil and also to polish the plate. After these middlings have served their purpose, the slivers of iron and tin are removed and the middlings with the absorbed palm oil are sold as tin plate by-product. Sometimes peanut meal is used in place of wheat middlings. The feeding value should be at least as great as that of ordinary wheat middlings.

Vegetable Meal. — Recently a process has been perfected by means of which garbage is dried, the oil removed, and the residue ground and used for stockfeeding. In the process of drying and removing the oil, the material is sterilized by heat. Inasmuch as no experiments have yet been reported upon this material we are unable to say anything

[1] Mass. Agr. Exp. Sta. Bul. 158.

as to its nutritive value. It ranges from 19 to 30 per cent in protein, depending largely upon its ingredients.

Yeast or vinegar dried grains are the dried residue from the mixture of cereals, malt and malt sprouts (sometimes cottonseed meal), obtained in the manufacture of yeast or vinegar. They consist of corn or corn and rye, from which most of the starch has been extracted, together with malt added during the manufacturing process to change the starch to sugars, and malt sprouts (sometimes cottonseed meal), added during the manufacturing process to aid in filtering the residue from the wort and serve as a source of food supply for the yeast. They are probably similar to dried distillers' grains in feeding value.

CHAPTER XIV

THE HAYS

Hay consists of the entire dried plant of the fine-stemmed grasses or of the legumes. Ordinarily the plant is cut at such times as to get the greatest amount of digestible nutrients and the least amount of crude fiber, and allowed to dry or cure in the sun. The curing process should not take place too rapidly or it will not have the pleasant aroma which well-cured hay should have. It will also be more brittle and more of the valuable leaves will be lost in putting it up.

Brown hay is made by stacking the hay when only partially cured. On account of the large amount of water which it contains, it undergoes fermentation with the production of considerable heat, which discolors or may even char the hay. The feeding value of brown hay is less than that of ordinary hay. However, it usually is very palatable and much relished by stock. It is commonly prepared in regions where climatic conditions make it difficult to thoroughly cure the hay.

Hay may be divided into two subclasses, the legume hays and the grass hays.

THE LEGUME HAYS

The most important legume hays are red clover and alfalfa. Of less importance are mammoth clover, alsike clover, sweet

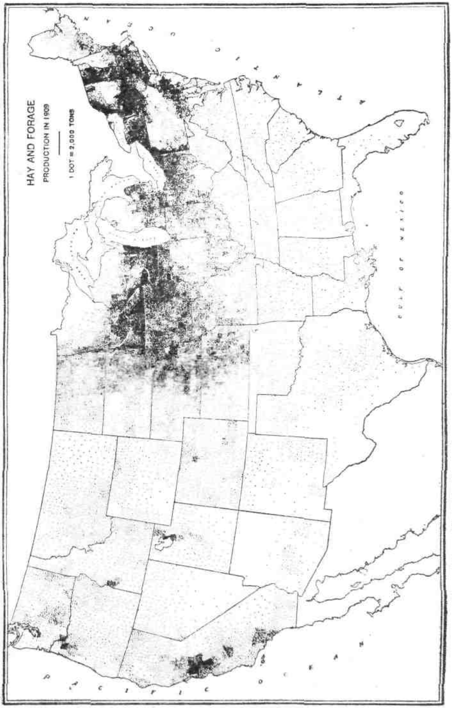

FIG. 49. — Distribution of hay and forage in the United States. (U. S. Census.)

clover, crimson clover, Japan clover, velvet bean, peanut, beggar weed, Canadian field pea, cowpea, soybean, and the vetches. *The legume hays are distinguished from the grass hays by their high content of protein and ash.* They also usually contain more ether extract. On account of their relatively high content of protein and mineral matter, they are particularly valuable in stockfeeding.

FIG. 50. — Red clover. (Livingston, Field Crop Production.)

Red clover hay is ordinarily spoken of in the corn-belt as "clover hay." It is the standard legume hay crop of the United States and Canada. It is grown extensively in the corn-belt as it fits in well with the ordinary crop rotations.

The average chemical composition of red clover hay is as follows: water, 15.0 per cent; ash, 7.7 per cent; crude protein, 13.3 per cent; crude fiber, 24.3 per cent; nitrogen-free extract, 37.2 per cent; and fat, 2.5 per cent. Its net energy value is 34.7 therms per 100 pounds. As the composition indicates, it is relatively high in muscle-building constitutents. The feeding value of clover hay depends to a large extent upon the time of cutting and the method of

curing. If the hay is cut too early it will not contain enough nutrients, while if it is cut too late it will contain more crude fiber and be less digestible. Clover should be cut when approximately one-third of the heads have turned brown. If the hay is leached by rain a large part of the more digestible portions are washed out. If it is put up too green, it will brown, mold, or fire; while if it is put up too dry, the leaves,

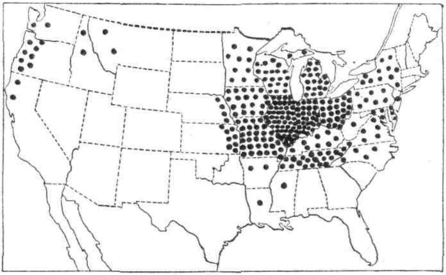

FIG. 51. — Production of clover in the United States. One dot represents 10,000 tons. (Hitchcock, A Text-Book of Grasses.)

which contain most of the nutriment, will be shattered off and lost.

For Growing Stock. — Due to its high content of crude protein and mineral matter, clover hay is one of the best roughages for growing stock.

For calves and growing cattle, clover hay is second only to alfalfa as a roughage. Owing to its bulkiness, concentrates should be fed along with it for quick growth, but for wintering stock cattle little or no other feed is necessary.

Clover hay, if bright, clean, and well-cured, may be used in limited amounts for colts and young horses. Mixed hay (clover and timothy) is also very good. Care should be taken not to feed dirty, dusty clover hay, as the dust may cause serious trouble by irritating the lungs of the horse. Clover hay is too bulky to use very extensively for growing pigs. It is excellent for lambs. In fact, it is almost indispensable unless alfalfa hay is available.

For Fattening Stock. — Clover hay may furnish a large part of the protein in the ration of the fattening animal. Especially is this true in the corn-belt, where corn is the principal concentrate used by the feeder.

For fattening cattle, clover hay, corn, and 2 to 4 pounds of linseed or cottonseed meal make an excellent combination. Unless silage is available, it is quite difficult to formulate a satisfactory ration for fattening cattle without including clover or alfalfa hay. Clover hay is too bulky for use with fattening hogs. When clover hay furnishes the entire roughage for fattening lambs or sheep, corn is the only concentrate necessary to produce good gains. The addition of a little linseed or cottonseed meal may increase the gains somewhat, but usually not enough to pay for the increased cost of the ration.

For Breeding Stock. — Owing to its high content of protein and mineral matter, clover hay makes a good roughage for all classes of breeding animals.

Breeding cows may be maintained through the winter on little or no concentrates if they have plenty of clover hay. The same precautions should be taken in feeding it to brood mares as have been mentioned in connection with its use for colts. If these precautions are taken, it is quite satis-

factory. In winter it may be fed in limited amounts to brood sows when they are not suckling a litter. For breeding ewes, good clover hay with little or no grain is sufficient to maintain them until within a few weeks of the lambing season.

For Milk Cows. — Clover hay furnishes a large amount of the crude protein and ash so essential to milk production. When it forms the sole roughage of dairy cows, as much as half of the concentrates may consist of corn. If a non-nitrogenous roughage is used, less corn and more nitrogenous concentrates must be fed. Either clover or alfalfa hay is almost essential for economical milk production.

Fig. 52. — An alfalfa plant. (Livingston, Field Crop Production.)

For Work Horses. — Clover hay is coming to be more generally fed to horses. When of good quality it may be used together with timothy hay for work horses. It should be of good quality, otherwise it will be too stemy and the dust will cause harm.

Alfalfa hay is probably the most valuable roughage grown. Although it is the principal hay of many of the semi-arid states of the West, alfalfa is not yet generally grown in the corn-belt. It is, however, becoming more extensively grown and it has its place on every corn-belt stock-farm. It has the advantage over clover of being more resistant to drought, of yielding better, and of having a higher feeding value.

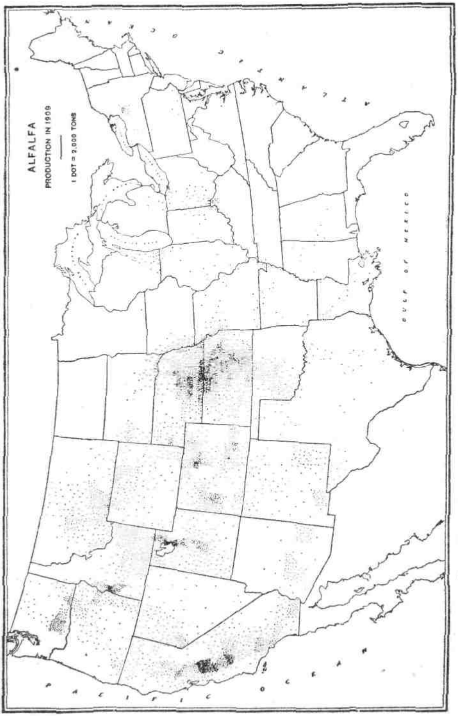

Fig. 53. — Distribution of alfalfa in the United States. (U. S. Census.)

Clover on the other hand is much easier to start and much easier to cure.

The average chemical composition of alfalfa hay is as follows: water, 8.1 per cent; ash, 9.1 per cent; crude protein, 14.7 per cent; crude fiber, 28.4 per cent; nitrogen-free extract, 35.8 per cent; and fat, 1.9 per cent. Its net energy value is 34.4 therms per 100 pounds. The feeding value of alfalfa hay depends to a large extent upon the quality. Good, well-cured alfalfa hay has a feeding value much greater than clover hay. Poorly cured alfalfa hay may have a feeding value considerably less. Therefore, considerable care must be exercised in the curing of alfalfa hay. If it is allowed to become dry and brittle before it is taken in, a large part of the leaves, which contain much of the nutritive value, will shatter off. On the other hand, if it is taken in too green, it will heat and mold, not only greatly decreasing its value as a feed, but also making the stack or mow liable to fire from spontaneous combustion. The first and last cuttings are especially difficult to cure.

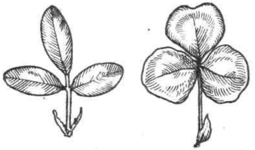

FIG. 54. — Arrangement of leaflets of alfalfa and clover. (Livingston, Field Crop Production.)

For Growing Stock. — Owing to its high content of protein and mineral matter, its palatability, and its general physical condition, well-cured alfalfa hay is the prime dry roughage for practically all growing animals.

Young cattle may be wintered on alfalfa hay with no concentrates and make a fair growth. Colts and young

horses may utilize considerable alfalfa by feeding timothy hay with it. Alfalfa leaves, or the entire plant fed whole, chopped, or ground may be utilized to advantage as a supplement to corn for growing pigs. It is the best roughage available for lambs.

For Fattening Stock. — Alfalfa hay is very good for all fattening stock except hogs. It furnishes a large part of the protein which otherwise would have to be furnished by expensive concentrates.

Only a small amount of nitrogenous concentrates is needed in a ration of corn and alfalfa hay for fattening cattle. Its use also materially decreases the amount of concentrates needed. Only small amounts of alfalfa hay should be used in the rations of fattening hogs, owing to their inability to handle large quantities of bulky feeds. It will usually pay to buy some less bulky nitrogenous concentrate as a supplement to corn for hogs. It is difficult to improve a ration of corn and alfalfa hay for fattening lambs or sheep. Alfalfa hay may be used quite extensively in the rations of horses which are being fattened for the market.

For Breeding Stock. — Alfalfa hay is very good for breeding animals, not only on account of its chemical composition, but also on account of its laxative effect.

Breeding cows which have free access to alfalfa hay need little or no grain during the winter. If not dusty, it is very suitable for brood mares. However, not only because of its cost but also because of its high protein content and laxative nature it is usually fed with some other roughage. It may be fed from racks to brood sows with very good results. Breeding ewes may be successfully wintered up until a few weeks of lambing time on alfalfa hay alone.

For Milk Cows. — Alfalfa hay may furnish 60 per cent of the protein of the ration of dairy cows with profit. In this case, fifty per cent or even more of the concentrates of the ration may consist of corn. It is not necessary, and usually not profitable, to use bran in the ration when it contains alfalfa as the roughage.

For Work Horses. — Alfalfa hay, if not dusty, is very suitable for work horses. When it is fed, there is no need of feeding nitrogenous concentrates in addition to corn. It is usually too laxative to furnish a very large part of the roughage of driving horses. It perhaps may give better results if fed with timothy hay, oats straw, or corn stover. Horses will maintain flesh better on alfalfa than on timothy hay. Late-cut alfalfa hay is preferable for horses.

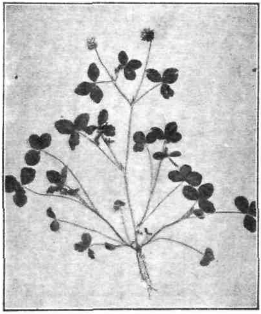

FIG. 55. — Alsike clover. (Livingston, Field Crop Production.)

Mammoth clover hay has about the same chemical composition as red clover hay. It is coarser and, consequently, less valuable as a feed. It will grow under more adverse conditions than red clover. It is several weeks later than red clover and yields but one cutting in a season. It is often grown with timothy as it is ready for cutting at about the same time as timothy. As

it grows very heavy and rank, it is often possible to pasture it early in the spring before it is cut for hay. It is practically as good for cattle as red clover hay, but not as valuable for horses, hogs, and sheep on account of the stems.

Fig. 56. — Sweet clover. (Piper, Forage Plants.)

Alsike Clover Hay is similar in chemical composition to red clover hay. Well-made alsike hay has a high feeding value, but the yield is usually too small to permit its being grown profitably if red clover can be grown. However, it may be grown successfully on land too acid or too wet for red clover. It should be grown with timothy or some other grass, as it usually has weak stems and will fall to the ground unless supported. Such a mixture makes a very good hay for horses, as it usually is clean and free from dust.

Sweet Clover Hay. — Quite generally regarded as a pest until recently, sweet clover is coming slowly into use as a feed for farm animals. It will grow on soil too poor in humus to grow red clover or alfalfa successfully. Owing to the tough seed coats much of the seed will not germinate the first year. The ordinary white sweet clover should be sown. Usually one crop of hay may be secured the first year and two crops the second year. Inasmuch as

the first season's growth does not usually get coarse and woody, it may be cut the first season when the plant shows its maximum growth in the fall. The second season the hay *should be cut just before the first bloom appears*, as the plant then rapidly becomes coarse, woody, and less palatable. It is rather difficult to cure, and care should be taken not to shatter off the leaves.

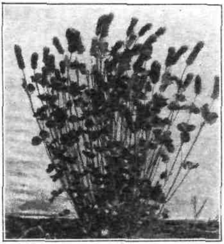

FIG. 57. — A crimson clover plant. (Livingston, Field Crop Production.)

In chemical composition, sweet clover hay is about the *same as alfalfa. In feeding* value, good sweet clover hay is a little less valuable than alfalfa hay. Its chief drawback is its bitter taste, which often causes animals to refuse it at first. The bitter taste is not present in the young shoots but only in the older, tougher stalks. However, stock can be readily induced to eat it, and once they acquire a taste for it no difficulty is experienced. It is used especially for cattle and sheep.

Crimson clover is an annual grown in the South Atlantic States. It does not make a satisfactory hay on account of the small, rigid, barb hairs which occur on the ripened head of the plant. These hairs may form balls in the digestive tract of the horse and cause serious trouble or even death. If it is used for hay, it should be cut at the time of blooming.

Japan clover, or lespedeza is an annual grown extensively in the South. It furnishes from one to four tons of hay per

acre. It is similar to red clover hay in chemical composition and equal to the best red clover hay in feeding value.

The velvet bean is an annual grown in the extreme South. It is very difficult to cure into hay on account of its rank growth. The vines are sometimes 75 feet long. It is a heavy yielder and ranks with other legumes in feeding value.

FIG. 58. — Field pea. (Piper, Forage Plants.)

The peanut is grown in the South. Hay made from the peanut vines is about equal to red clover in feeding value.

The beggar weed is an erect annual from 3 to 10 feet high. It is used in the South for hay. It has a very rank growth, often yielding 4 to 6 tons per acre. In feeding value the hay is probably a little below red clover.

Canada field peas, grown in Canada and the northern states of this country, are sometimes used for hay. Well-cured peavine hay is about equal to red clover in feeding value. Peas are often seeded with oats. The oats support the peas, so that mowing is easier.

Cowpea hay is used quite generally in the South, although it is not generally used in the North, where the

other legumes may be more successfully raised. In the corn-belt, it can be grown to advantage sometimes as a catch crop, especially after the failure of clover. Cowpea hay is rather difficult to cure. In composition and feeding value, it closely resembles alfalfa. It is especially valuable for dairy cows.

FIG. 59. — Cowpea. (Piper, Forage Plants.)

Soybean hay, although little used, ranks in feeding value with the other legume hays. Soybeans may be grown as a catch crop.

Common vetch, often grown with barley, oats, wheat, or rye, is quite generally used on the Pacific coast and in the South as a hay. It is seeded in the fall usually. Hairy vetch can be grown in the corn-belt. The United States Department of Agriculture[1] states that it can be used to seed in the corn at the last cultivation to furnish a subsequent crop for green manuring or for hay. Hairy vetch is one of the best legumes to use where red clover is not a success. This is especially true

[1] Farmers' Bul. 515.

in sandy soils. Vetch hay is at least as valuable as red clover hay.

THE GRASS HAYS

The principal grass hay of the corn-belt is timothy. Other grasses which are sometimes grown for hay are the millets, the sorghums, Sudan grass, red top, orchard grass, Bermuda grass, Johnson grass, prairie grass, brome grass, tall oat grass, Italian rye grass, slender wheat grass, western wheat grass, rye, oats, and barley. Unlike the legume hays, most of the grass hays are deficient in protein and consequently they are not as valuable for most feeding purposes. They have the advantage of being more easily grown and more easily cured than the legume hays.

FIG. 60. — A soybean plant. (Livingston, Field Crop Production.)

Timothy Hay. — Timothy is familiar to all as it is very widely and easily grown. The hay is easily cured and unusually free from dust. The objections to timothy are its low-feeding value and the fact that it is very hard on the soil. These objections may be partly obviated by sowing alsike or red clover in it.

The average chemical composition of timothy hay is as follows: water, 13.2 per cent; ash, 4.4 per cent; crude protein, 5.9 per cent; crude fiber, 29.0 per cent; nitrogen-free extract, 45.0 per cent; and fat, 2.5 per cent. Its net energy value is 33.6 therms per 100 pounds.

FIG. 61. — Hairy vetch. (Piper, Forage Plants.)

On account of its low content of protein, it cannot be regarded as a satisfactory roughage for growing or breeding animals unless they receive considerable amounts of nitrogenous concentrates in addition. Such animals should have considerable wheat bran. If fed as the exclusive roughage to fattening cattle and sheep, the concentrates should be rich in nitrogenous feeds, as linseed meal, gluten feed, cottonseed meal, or wheat bran. Even then the results in most cases will not be as satisfactory as when corn alone is fed with clover or alfalfa hay. Usually the market value of timothy hay and the cost of the nitrogenous concentrates make it too expensive for such feeding. Timothy hay is often given too high a value as a feed for the milk cow. When it forms a large part of her roughage, a very large

proportion of the concentrates should consist of nitrogenous feed, such as bran, gluten feed, linseed meal, cottonseed meal, etc. Only a small amount of corn should be used in such a ration. Even then the best results will not be obtained. For horses, however, timothy hay is the standard roughage. It is practically *the only roughage used for* horses in the city. It is also extensively used on the farm. The reasons for its preëminence as a roughage for horses are as follows: (1) it is free from dust; (2) there is little loss in handling it; (3) it is very palatable when cut at the proper stage; (4) it does not produce too much laxness of the bowels; and (5) it gives the necessary bulk and volume to the ration. Timothy hay which contains some clover is better for foals, young horses, and brood mares on account of the higher protein content.

Fig. 62. — Timothy. (Piper, Forage Plants.)

The Millets. — The principal millets used for hay in the United States are foxtail millet, including the varieties common, German, Hungarian, etc.; broom-corn or hog millet; and Japanese barnyard millet. Common, German,

and Hungarian millets are frequently grown as catch crops in the corn-belt. Thickly seeded, early cut millet hay is recommended by many authorities as useful for cattle and sheep feeding. It should be fed sparingly to horses as it may cause kidney disturbances.

Their feeding values are quite low, however, and the author does not advise their general use, although they

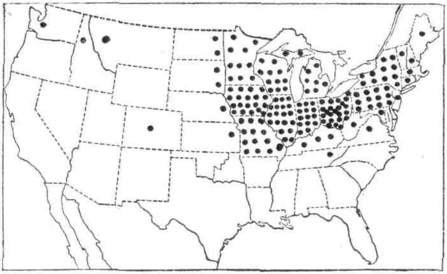

FIG. 63. — Production of timothy in the United States. One dot represents 100,000 tons. (Hitchcock, A Text-Book of Grasses.)

may have their place at times when there is a general scarcity of hay.

The sorghums used for hay include the sweet sorghums, the kafirs, milo, feterita, and Sudan grass. The other sorghums are less valuable for hay. When used for hay the sorghums should be seeded thickly so as to prevent a coarse growth. They should be cut at the late milk stage. They are probably about equal to timothy hay in feeding value.

Sudan grass was introduced into the South a few years

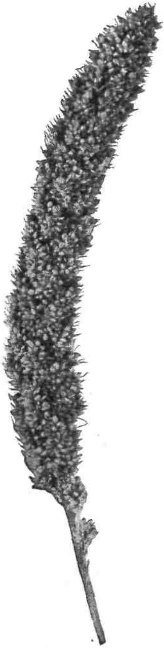

FIG. 64.—Common millet. (Voorhees, Forage Crops.)

ago and quite recently into the corn-belt. It is a drought-resistant plant. Like the other sorghums, it should be seeded thickly to prevent it from becoming too coarse. It should be cut for hay when the heads are in bloom or earlier. It is a very heavy yielder, and the hay is not as coarse as that from the other sorghums. In feeding value it is about equal to timothy hay. It is often sown with cowpeas or soybeans.

Red top is especially valuable on damp lowlands. It is grown extensively for hay in New England and is also grown to considerable extent in southern Illinois and in the South. However, its use is not restricted to any particular locality. It yields a fairly palatable hay lower than timothy in feeding value.

Orchard grass is especially adapted to shady places. It is grown mostly in the South. It is about two weeks earlier than timothy. It should be harvested early. The hay is woody, unpalatable, and not especially relished by stock if cut after bloom.

Bermuda grass is grown quite extensively in the South. It is to the cotton-belt what bluegrass is to the

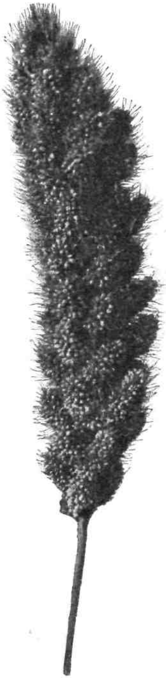

Fig. 65. — German millet. (Voorhees, Forage Crops.)

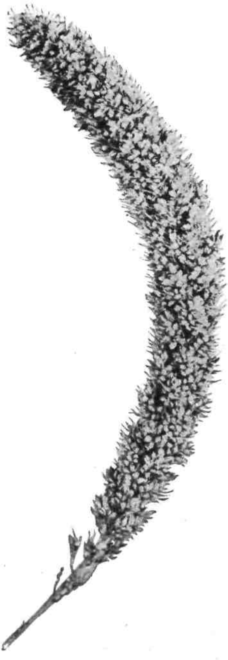

Fig. 66. — Hungarian millet. (Voorhees, Forage Crops.)

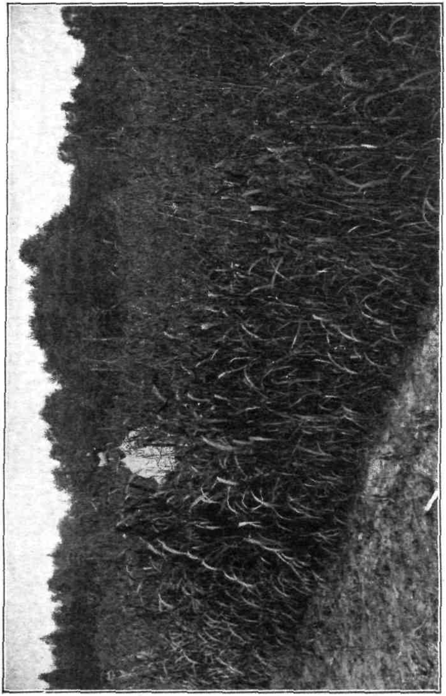

FIG. 67. — A field of Sudan-grass. (Piper, Forage Plants.)

corn-belt. It yields a large amount of hay which is about equal to timothy in feeding value.

Johnson grass is an important hay crop in the South. It gives a heavy yield of hay which has a fair feeding value. Johnson grass has the objection that it spreads very rapidly and may become a pest.

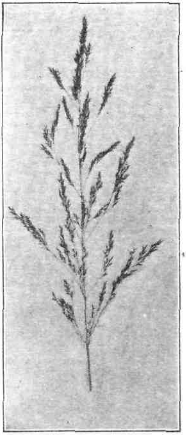

Fig. 68. — Red top. (Livingston, Field Crop Production.)

Prairie hay is made from the native grasses found on the western prairies. The upland hay is preferable to the midland and lowland hay. It is much used in the West and has a fairly high feeding value, being better than timothy.

Brome grass is a very important pasture and hay grass in Kansas, Nebraska, the Dakotas, Manitoba and Saskatchewan. It is quite resistant to cold. In feeding value it is superior to timothy. It is more palatable than timothy.

Tall oat grass is one of the best perennial grasses for poor land. Also it will withstand considerable drought. However, it is not grown extensively in the United States, but it is grown to some extent in the South. It makes a fair hay, but is not very palatable.

Italian rye grass is grown for hay to a certain extent in the Atlantic States and on the Pacific coast. In France and

England it furnishes the largest proportion of the market hay. It makes a fairly palatable hay.

Slender wheat grass, sometimes called western rye grass, is grown to a considerable extent in Manitoba, Alberta, Saskatchewan, and the Dakotas. The hay is comparable to timothy in feeding value.

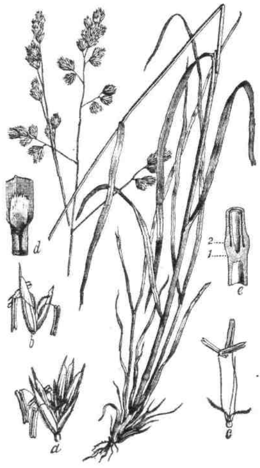

FIG. 69. — Orchard-grass. (Piper, Forage Plants.)

Western wheat grass is also known as blue-stem, blue-joint, and Colorado blue-stem. It is quite resistant both to drought and to alkali. It grows native over a large part of the West and the hay is valuable for horse feed.

Rye, Oats, and Barley. — Fall-sown rye and spring-sown oats or barley are sometimes used in the corn-belt to furnish a quick-growing, excellent, dust-free, and palatable hay. When used for this purpose, the cereals should be harvested before maturity while in the milk. Oats or barley sown with alfalfa as a nurse-crop are usually cut for hay after the young alfalfa gets a good start. Barley is used to a considerable extent for hay on the Pacific

coast. In feeding barley hay care must be taken to remove any of the beards which may have become lodged in the ani-

FIG. 70. — Bermuda-grass. (Piper, Forage Plants.)

mal's tongue or mouth. Although these hays have a fairly high nutritive value, it is not likely that they will ever assume much importance in the corn-belt, on account of their high cost.

CHAPTER XV

FODDERS AND STOVERS

THE term fodder may have several meanings. Many of the older writers upon the subject of stock feeding call any feedingstuff a fodder regardless of its nature. Of the more recent authorities, some limit the term to roughages in general, while others apply the term to the entire cured plant of the large, coarse grasses, such as corn, sorghum, kafir corn, feterita, and milo maize. For the purpose of this book, the latter system of terminology has been adopted. The term stover is applied to the cured stalk, leaves, and husks of these plants after the grain has been removed.

Corn fodder in the corn-belt refers to the entire corn plant, *i.e.* stalk, leaves, husk, and ears, cut when ripe. It is also known as shock corn. North, south, and west of the corn-belt the term corn fodder refers to corn which is planted thickly and cut while it is still comparatively green. It contains only a few small ears. Inasmuch as corn is seldom treated in this manner in the corn-belt, we shall limit the meaning of the term to the entire mature corn plant, grown and cut in the ordinary way.

The average chemical composition of corn-belt corn-fodder is as follows: water, 18.3 per cent; ash, 4.0 per cent; crude protein, 6.7 per cent; crude fiber, 17.0 per cent; nitrogen-free extract, 52.1 per cent; and fat, 1.8 per cent. However, the composition may vary greatly, depending to a

large extent upon whether the fodder is allowed to remain in the field or is put in the barn. Thus, at the Illinois Station corn fodder which was allowed to remain in the shock contained 32 per cent of water, while corn fodder which was placed in the barn contained only 7 per cent. Further, corn fodder which is allowed to remain in the shock will lose a considerable part of the more digestible nutrients by leaching. Hence, it should be placed under shelter if possible.

Corn fodder is as valuable for feeding to cattle as the same amount of ear corn and corn stover. Thus, if cattle are kept, there is no necessity of going to the labor and expense of husking all the corn on the farm, although part of it should be husked in order that the proper proportion of concentrates and roughages may be supplied at all times. Corn fodder consists of about 50 per cent grain and 50 per cent stalk and leaves.

Fattening cattle do very well upon a ration of corn fodder supplemented by ear corn and linseed meal. Dairy cows also can utilize corn fodder to the extent of half their roughage. In this case, it is not necessary to add shelled or ground corn to the ration, but nitrogenous concentrates should be given. However, corn fodder is not as valuable for the dairy cow as for the fattening steer. Sheep will utilize some corn fodder, although they generally leave a considerable amount of the coarser parts. Horses should not receive corn fodder exclusively. Work horses have not the time to digest it, and colts and brood mares need additional protein in their ration. Obviously, corn fodder is too bulky for use with hogs, although they will, of course, eat the grain from the husk.

The sweet sorghums or sorgos can be grown successfully almost anywhere in the United States. They are drought-resistant and, consequently, they are extensively grown in the South and Southwest both for the production of molasses and as a stock-feed. After periods of extreme drought, or an early frost, sorghum often contains prussic

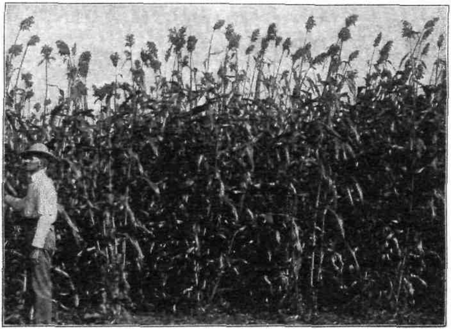

FIG. 71.—A field of orange sorghum. (Voorhees, Forage Crops.)

acid, which is deadly poison. Second-growth sorghum also sometimes contains prussic acid. Hence, considerable care must be exercised in feeding it. Thoroughly cured sorghum fodder may be fed with little danger. In feeding value it is about equal to corn fodder. Sweet sorghum fodder, if left in the field, is likely to sour after about three months, due to the fermentation of the sugar which it contains.

Kafir corn, feterita, and milo maize are closely related

Fig. 72. — A field of black-hulled white kafir. (Duggar, Southern Field Crops.)

to the sweet sorghums. They are very resistant to drought and hot weather and are grown extensively in Kansas, Oklahoma, Texas, and California. They are not grown to any great extent in the corn-belt. In feeding value, their fodders are about the same as corn fodder. Like the sweet

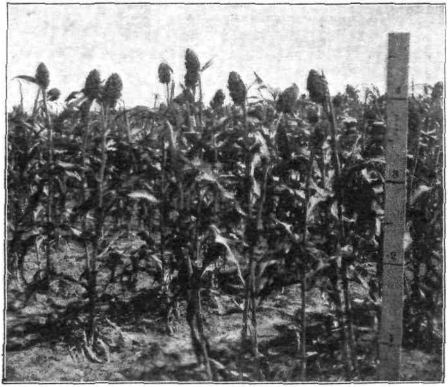

Fig. 73. — A field of milo. (Montgomery, The Corn Crops.)

sorghums they often contain prussic acid after the growth has been stunted by extreme drought or by frost.

The broom-corns, kowliangs, and shallu also belong to the sorghums. They have dry, pithy stems and, consequently, their fodders are not as valuable for feed as those of the other sorghums.

Corn Stover. — As previously stated, corn stover refers to the entire corn plant after it has been cut and the ears husked out. The average chemical composition of corn stover as determined by analyses made in the corn-belt is as follows: water, 17.0 per cent; ash, 6.3 per cent; crude protein, 5.6 per cent; crude fiber, 28.0 per cent; nitrogen-free extract, 42.1 per cent; and fat, 1.0 per cent. As in the case of corn fodder, the method of storage has considerable influence upon the chemical composition. Thus, the water content may vary from 10 per cent in the case of stover stored in the barn, to 55 per cent in the case of stover allowed to remain in the field. As in the case of corn fodder, exposure to rain and snow will cause a considerable loss of the most digestible nutrients of the stover.

The feeding value and possibilities of corn stover are usually underestimated. Especially is this true in the central and western parts of the corn-belt, where only a small percentage of the corn crop is cut. As a matter of fact, the stover contains from one-fourth to one-third of the feeding-value of the entire corn crop.

Corn stover may profitably furnish from one-third to one-half of the roughage when fed with clover or alfalfa hay to fattening cattle. It may furnish a large part of the ration of stock cattle which are being wintered without making any gain. Also, it may form a large part of the ration of breeding cows and breeding ewes. For milk cows it has about the same value as timothy hay and should be used in only limited amounts. Corn, linseed meal, and corn stover will produce fair, though not maximum, gains with fattening sheep. It may be fed also to horses, especially in winter, when they are not at hard work. For this purpose, it has

a value only slightly below that of timothy hay. It is said to be much better than good hay for horses with heaves, owing to its being free from dust.

Shredding corn stover does not increase its value as a feed but it does make it much easier to handle and store, and more valuable as a bedding.

Sweet sorghum, kafir, feterita, and milo stovers are the stalk and leaves of these plants after the grain has been removed. In feeding value, they are about equal to corn stover.

Kowliang and shallu stover are not as valuable as stover from the other sorghums.

CHAPTER XVI

THE STRAWS

STRAW consists of the stems and leaves of the cereals and legumes after the ripe seeds have been threshed out. The plant, as it approaches maturity, transfers its food material from the stem and leaves to the seed, leaving the stem and leaves low in all the nutrients except crude fiber which, as has been shown, is quite indigestible. Thus the straws are very low in digestible nutrients and net energy. In addition, they are quite unpalatable. Consequently, their nutritive value is usually rather low.

Straw may often be used to advantage when damp or uncured hay is put in the mow or stack. A layer of hay followed by a layer of dry straw will enable one to put in hay which otherwise would mold. This practice also secures an increased consumption of the straw as it adds greatly to its palatability. This method is especially recommended for alfalfa and clover when the weather is unfavorable to their proper curing. It not only lessens the danger of the hay molding, but it prevents the hay from becoming too brittle and the leaves from shattering off. Inasmuch as it is often more economical to feed straw with clover or alfalfa hay, nothing is lost by the method.

The leading straws used for stock feeding are oats, barley, wheat, and rye. Of less importance are threshed timothy, red top, millet, flax, clover, alfalfa, soybeans, and cowpeas.

Oat Straw. — The most valuable straw for feeding is oat straw. Its chemical composition is as follows: water, 9.2 per cent; ash, 5.1 per cent; crude protein, 4.0 per cent; crude fiber, 37.0 per cent; nitrogen-free extract, 42.4 per cent; and fat, 2.3 per cent. The net energy value is 21.2 therms per 100 pounds.

Oat straw is one of the best of the non-nitrogenous roughages for fattening cattle and sheep, being equal to timothy hay. It is especially valuable when fed with corn and corn silage. It should be supplemented by nitrogenous concentrates or legume hays. Milk cows also may use some oat straw to advantage. Breeding and stock cattle can use large amounts of oat straw to good advantage, as can also breeding ewes. Horses that are not at work may also use it. It is too bulky for horses at hard work.

Barley straw ranks next to oat straw in feeding value. However, it should not be used to any great extent for fattening stock, milk cows, or work horses. It may be used as a part of the roughage for stock cattle and breeding animals, except hogs.

Wheat straw has a lower feeding value than barley straw. It may be used as a part of the ration for wintering cattle and sheep when no gain is desired.

Rye straw has a lower feeding value than wheat straw. It is best suited for bedding.

Timothy, red top, millet, and flax straw have but little feeding value. They may be used to a certain extent in wintering stock cattle and sheep.

Clover, *alfalfa*, soybean, and cowpea straw contain more crude protein than the non-legume straws. Threshed clover and alfalfa may be used as a part of the roughage for stock

cattle, and for breeding cattle and sheep. Alfalfa straw or chaff is often ground and used in alfalfa, molasses feeds or sold as alfalfa meal. When so used it is quite difficult to detect. Soybean and cowpea straw are sometimes used for fattening cattle and sheep with fair results. The condition of the straw will determine to a large extent its value as a feed.

CHAPTER XVII

PASTURE OR FORAGE, AND SOILING CROPS

Pasture or Forage Crops. — Different authorities upon stock feeding make different and often vague distinctions between the terms forage and pasture. In fact few of them make the same distinction. Consequently, we shall regard the two terms as synonymous, although, as stated, a distinction between them is often made. For the purpose of this book, any crop which is harvested by the animals themselves may be regarded as a pasture or forage crop. Although a pasture of forage crop is usually harvested in a green or unripe condition, as in the case of clover pasture, such is not always the case, as in the case of pasturing stalk fields after the corn has been harvested.

Pasture is almost essential to the successful breeding of all classes of live stock. Pastures may be divided into two general classes, permanent and temporary. A permanent pasture is one which is allowed to remain for a considerable period of time. Permanent pastures are more generally used on land which is too rough or too low in fertility to make cultivation profitable, or they are used on cheap land where labor is high. Many farmers on rough, thin, cheap land would make more from their land if it were in permanent pasture than they do by cultivating it. However, there is considerable permanent pasture on corn-belt land which is

well adapted for growing the cultivated crops. It may be doubtful if one can profitably keep $200 land in permanent pasture. If one is breeding cattle, horses, or sheep to any extent, it probably will be profitable to keep some permanent pasture. Otherwise, it probably will be more profitable to depend upon temporary pastures. Temporary pastures usually are used for only a year or two and are then turned under and a cultivated crop put in. They usually are used as a part of nearly all good rotations and thus are of value not only from the standpoint of their nutritive value but also from the standpoint of their fertilizing value. Unlike permanent pastures, no live stock farmer can afford to be without temporary pastures.

Soiling Crops. — A soiling crop is one which is cut green and supplied to animals in confinement. Soilage is one of the most intensive forms of farming. It is more to be recommended to dairy specialists than to followers of other systems of live stock farming. It is commonly practiced in Europe, in the eastern part of the United States, and in the immediate vicinity of some of the larger cities where land is very expensive and labor relatively cheap. In the best systems of soiling, such crops as rye, clover, alfalfa, oats, peas, early and late corn, sorghum, etc., are planted at such a time as to insure a continuous supply of green, though fairly mature, feed from early spring until late fall. Thus by the time one green crop is gone, another is ready to take its place. The feeding value of soiling crops is about the same as that of the same crops when pastured.

Burkett[1] makes the following suggestions for a soiling scheme. "Among the best soiling crops the following may

[1] "Feeding Farm Animals," p. 299.

be mentioned: peas and oats, rye, alfalfa, clover, vetch and wheat, soybeans, cowpeas, corn, millet, sorghum, and rape. On some farms green crops are fed throughout the season. In a general way the practice includes the rotation somewhat as follows, with substitutes in certain cases where the season has unfavorably influenced the usual order or makes possible the use of some local crop:

"*a.* Winter rye or wheat, to be cut in May.

"*b.* Green alfalfa, to be used any time.

"*c.* Green clover, cut and fed in June.

"*d.* Peas and oats, sown early in spring, with a succession at two or three intervals.

"*e.* Corn or sorghum, planted as early as possible, to be used during July and August.

"*f.* Millet, planted in June or early July, and fed in August.

"*g.* The land from which the peas and oats and early corn are removed may be seeded to millet for August feeding."

A number of rotations for soiling have been worked out for different localities. These tables usually give the crop to plant, the amount of seed per acre, the time of seeding, the area for ten cows, and the time of cutting.

The main advantage of soilage over pasturage is the much larger amount of feed which may be removed from the land, as an animal on pasture, by tramping, defecating, urinating, slobbering, etc., destroys more feed than it eats. Also one may often get two crops off a part of the land in one year. Thus, one acre in soiling crops may support as many animals as two or three acres in pasture. The disadvantages of soiling are the greater expenditure for labor, seed, and fertilizer in producing the crops, and the greater expenditure for labor in cutting and hauling them to the

stock. The labor proposition alone is sufficient to prevent soiling ever becoming very popular in the corn-belt, except upon high-priced land near the cities.

However, partial soiling often may be practiced successfully in the corn-belt. In the summer when flies are bad, it may be profitable to cut the pasture crops and haul them to the stock which are kept in cool, dark, comfortable

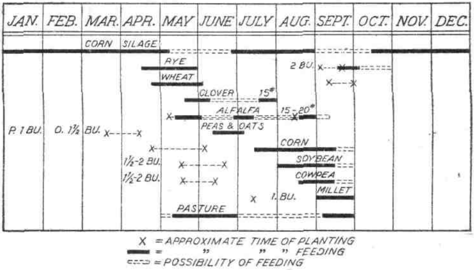

FIG. 74. — Showing seed per acre, approximate time of planting and feeding different soiling crops. (Illinois Experiment Station.)

quarters during the day and turned out to graze at night. If one desires to feed green alfalfa to cattle it is best to cut it and carry it to the stock rather than pasture it, for reasons already mentioned. In seasons of exceptional drought, when the pastures are all gone, it is often feasible to cut green corn or other crops and feed them to the stock in order to help tide them over until the pasture comes again.

Hayden, at the Illinois Experiment Station,[1] suggests the

[1] Cir. 152.

system of soilage for dairy cows for Illinois as given in Figure 74.

Of course, this plan may be modified to suit various conditions.

Inasmuch as the practice of soilage is quite complicated, and as it is but little used in the corn-belt, we shall confine our discussion of it to these few remarks and refer the student to other sources for more detailed information.[1]

In general the pasture and soiling crops may be divided into two sub-classes, legumes and grasses.

LEGUMES

The principal legume used for pasture in the corn-belt is red clover. Others of importance in the United States are alfalfa, mammoth clover, white clover, alsike clover, sweet clover, crimson clover, Japan clover, velvet beans, peanuts, beggar weed, Canada field peas, cowpeas, soy beans, and vetch.

Red clover should be grown on every farm in the corn-belt where alfalfa is not grown. Its value as a hay has already been noted. As a pasture and soiling crop it is no less valuable. No other clover, excepting sweet clover, furnishes as much pasture in one season, and no other clover is as palatable.

The average chemical composition of red clover pasture is as follows: water, 70.8 per cent; ash, 2.1 per cent; crude

[1] Henry and Morrison, "Feeds and Feeding," p. 264. Burkett, "First Principles of Feeding Farm Animals," p. 289. Jordan, "The Feeding of Animals," p. 263. Voorhees, "Forage Crops," p. 27. Conn. (Storrs) Bul. 9; Reports, 1891, 1895. Maryland Bul. 98. Mass. Reports, 1887–1891, 1893; Bul. 72, 133. New Jersey Bul. 158; Report, 1902. Penn. Reports, 1889, 1904–1905; Bul. 65, 75, 109. Vermont Bul. 158. Wis. Report 1885; Bul. 103, 235. Iowa Bul. 15, 19, 23, 27. Mich. Bul. 223.

protein, 4.4 per cent; crude fiber, 8.1 per cent; nitrogen-free extract, 13.5 per cent; and fat, 1.1 per cent. Its net energy value is 16.2 therms per 100 pounds. In chemical composition it is not much different from bluegrass. It is a little higher in protein and a little lower in ash. It is not as safe a feed, however, as is bluegrass. When clover is rank and succulent, cattle, sheep, and horses must be grazed on it with caution, especially at first, to avoid bloating. This danger may be lessened by having the animals full of dry hay before turning them into clover, by turning them in at first for only an hour or two when the dew is off and the pasture is as dry as possible, and by keeping dry hay or straw accessible to them in the pasture. Clover pasture should not be grazed too closely, and stock should be kept off when the ground is very soft, as it is rather easily killed. Clover is often used for pasture after the first cutting has been used for hay.

Clover pasture is recommended for all classes of farm animals if care is taken to prevent bloat. It is doubtful if it is profitable to feed any grain to milk cows which are on good clover pasture. If rapid fattening is desired, corn should be fed to steers on clover pasture. Ordinarily, however, this is not done. Grain is not necessary for breeding cows and calves on clover pasture. It is well to give colts on clover pasture some grain.

Clover pasture furnishes about a maintenance ration for hogs; hence if any fattening is desired, grain should be fed with it. Two or three pounds daily per 100 pounds of pig of a mixture of ten parts corn and one part tankage should be sufficient for good fattening gains. No more grain should be fed than they will clean up. If corn is very high in price,

it will be profitable to cut down the grain ration and make them eat more clover. In general, the greatest economy of forage for hogs is brought about when they are fed from one-half to two-thirds of a full-feed of grain in addition to the pasture. The number of hogs that may be kept on an acre of clover will depend on the abundance of the forage and the size of the hogs, but in general eight to twelve head may be used on good clover.

Alfalfa, although probably the most valuable hay, is not adapted to heavy pasturing, especially in the corn-belt, as a little tramping soon kills it. However, if one pastures it only lightly, the results are nearly as bad, as the top of the plant must be removed when the little shoots come at the base of the plant in order for it to make a satisfactory growth. Probably the most successful way to pasture alfalfa is to turn a comparatively small number of animals into a field of it and then cut it for hay when the shoots come up at the base of the plant. In this way, not much is tramped out, as the animals ordinarily will travel in run-ways and eat only along the edges of these run-ways. The alfalfa is then cut for hay when the shoots appear at the base. Alfalfa is much better for soiling than for pasture. Green alfalfa, especially when wet, has a very decided tendency to cause bloat. Hence considerable care should be exercised in its use.

Alfalfa pasture is excellent for cattle and sheep of all kinds. The trouble is that, unless the precautions mentioned above are taken, the stock are not good for the alfalfa. There is perhaps no forage crop which will produce as much pork per acre as alfalfa. Many breeders report that brood mares are difficult to get in foal when turned on alfalfa pasture.

Colts may be pastured on alfalfa, but it is probably not profitable in the corn-belt, although it may be so farther west.

Mammoth clover is a valuable pasture and soiling crop, being equal to red clover. If not pastured too heavily in the spring, it may be cut later for hay.

White and alsike clovers are occasionally used as pasture crops, but usually with timothy or bluegrass, as they add materially to the feeding value of either of the latter crops. In feeding value they are equal to red clover. White clover is said to cause excessive "slobbering" in horses. It is claimed by some horsemen that wet alsike poisons the noses, faces, and legs of white-faced and white-legged horses. It is very doubtful if this is true, however.

Sweet Clover. — Being one of the legumes, sweet clover is rich in protein and mineral matter. It makes excellent pasture for horses, sheep, cattle, and hogs. Its feeding value is about the same as that of red clover. It is said that it is not as liable to cause bloat as red clover or alfalfa. Ordinarily, stock dislike the taste of it at first, but by creating an appetite for it by turning them in early in the spring before other green feed has been started, they soon learn to relish it. It should be pastured heavily enough to keep it eaten down closely, so that there will be an abundance of fresh shoots for grazing purposes at all times, as animals dislike the hard, woody stems which contain the bitter tasting substance, cumarin; clipping with the mower from time to time will answer the same purpose. An acre of sweet clover often will support 15 to 20 hogs. They should be "rung," however, to prevent them from injuring the roots. After a few years sweet clover usually dies out and is supplanted by bluegrass.

Crimson clover is much better for pasture than for hay, owing to danger from the barbed hairs on the cured blossoms. For pasture it is equal to red clover in feeding value, but it is not as good a yielder in the corn-belt. It can be pastured in the spring about two weeks earlier than red clover.

Japan clover, or lespedeza is valuable as a pasture for all classes of farm animals. Though they usually do not like it at first, they soon learn to relish it. It is considered to be the best pasture crop for the poor, clay soils of the South. It is equal to red clover in feeding value. It does not cause bloat. It will withstand heavy pasturing and will maintain itself indefinitely if not pastured too heavily.

Velvet beans are used sometimes for pasture in the extreme South. Owing to the viny nature of the plants, they are usually grown with corn, millet, or sorghum to support the vine. They are pastured after the pods have matured in the fall. They are quite valuable and furnish an enormous amount of roughage. It has been said that they cause abortion in cattle and hogs and blind staggers in horses, but this is not true.

Peanuts make an especially valuable forage in the South for hogs. The hogs are turned in and allowed to root up the peanuts. The tops of the plants are also valuable for other classes of live stock.

Beggar weed is sometimes grown in the extreme South for pasture. It is well liked by stock.

Canada field peas are often grown in Canada and northern United States for pasture and for soiling. They are sometimes grown with oats and sometimes grown alone. They are especially valuable for sheep- and hog-pasture. Hogs are turned in when the peas are full-sized, while they are

allowed to mature for sheep. No other feed need be given to either sheep or hogs on pea forage. They are also good for milk cows, and are often used for soiling.

FIG. 75. — Field of velvet beans. (Duggar, Southern Field Crops.)

Cowpeas, owing to the large amount of protein and mineral matter which they contain, furnish an admirable pasture, especially in the South. Certain varieties may be grown

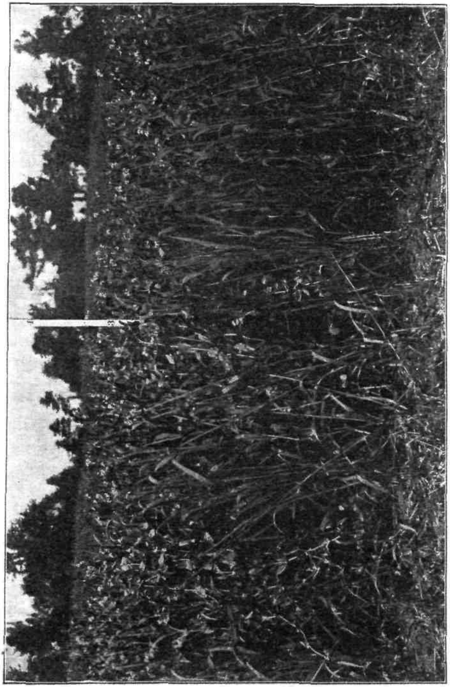

Fig. 76. — A field of oats and peas. (Voorhees, Forage Crops.)

successfully in the corn-belt. They may be used as pasture for all classes of live stock, but probably most profitably with hogs. For hog pasture they may be sown alone, planted with corn, or sown in the corn after the last cultivation. If hogs have access to cowpeas, no additional nitrogenous feed need be given, but they should have a two-thirds feed of corn. As a pork producer, cowpea pasture ranks considerably below clover, alfalfa, or rape pasture.

Soybeans. — Like cowpeas, soybean forage is used principally for hogs. Hogs relish soybeans better than cowpeas. Carmichael and Eastwood, at the Ohio Experiment Station, [1] found that clover, rape, soybeans, and bluegrass as forages for pork production ranked in the order named. A one-half full-feed of corn to hogs on soybeans will result in good gains. Soybeans may be planted in the corn for hog pasture, but cowpeas are much better suited for this purpose.

Common vetch *is often used for pasture in the West along* the Pacific coast. **Hairy vetch** may be used in the corn-belt. It furnishes a valuable pasture, ranking in feeding value with alfalfa. It should be seeded with a cereal, such as oats or rye, to furnish support to the weak vetch vine. It is quite valuable for soiling.

GRASSES

The leading grasses used in the corn-belt for pasture are Kentucky bluegrass and timothy. Other grasses used for pasture are Canada bluegrass, the millets, the sorghums, red top, orchard grass, Bermuda grass, Johnson grass, brome grass, rye, oats, barley, wheat, corn, perennial rye grass, and meadow fescue.

[1] Bul. 242.

Kentucky bluegrass is the preëminent grass of the permanent pastures of the corn-belt. It is also called June grass. It is not adapted to temporary pastures as several seasons are required to bring it to a maximum growth. However, after it once gets a good start, it will last for years if properly cared for. In order to use bluegrass successfully, one must have a knowledge of its habit of growth. The plant begins growth early in the spring and bears seed late in May or early in June. Then a dormant period of several weeks follows during which there is little growth. The midsummer and fall rains revive the plants, and another period of growth ensues, during which the plants store nutrients for the coming season's seed-bearing. Thus, one should not rely upon the grass for a steady and uniform feed supply throughout the entire season. It should not be stocked, certainly not heavily, before May or June, although sometimes the general practice seems to be to turn stock on pasture early in the spring before the grass gets a start and while it is still "washy." Sometimes it is profitable not to stock heavily until late summer, keeping the stock on it until early winter. It should not be grazed too closely.

The chemical composition of bluegrass is as follows: water, 65.1 per cent; ash, 2.8 per cent; crude protein, 4.1 per cent; crude fiber, 9.1 per cent; nitrogen-free extract, 17.6 per cent; and fat, 1.3 per cent. It is the richest grass in crude protein, ash, and fat. In addition to this, its palatability makes it relished by all classes of live stock.

Bluegrass pasture is almost a necessity for the successful breeding of any class of farm animals. It makes an ideal ration for the mare and colt, the cow and calf, and the ewe and lamb. The sow and pigs are also greatly benefited by

FIG. 77. — Panicles of Canada blue grass (left) and Kentucky blue grass (right). (Piper, Forage Plants.)

having the run of a bluegrass pasture in addition to their concentrates. Milch cows do well on it. They may give more milk if given a few pounds of grain in addition to the pasture, but the cost of production is increased and the practice may not be economical. For fattening cattle, sheep, and hogs, bluegrass pasture makes an admirable roughage. If rapid fattening is desired, grain should be given in addition. If only fair gains are desired, no grain need be fed except in the case of hogs. Hogs on bluegrass should receive one-half to a two-thirds full-feed of concentrates. In certain parts of Virginia and West Virginia, many cattle are fattened for the export trade, attaining a very superior finish upon bluegrass pasture alone without the use of any grain. Work horses may be turned out on bluegrass at night after they have eaten their grain.

It usually requires 1 to 2 acres of bluegrass for a horse or cow. One acre of good bluegrass will provide forage for 10 to 14 hogs or 5 to 7 sheep. It is maintained by many that one cannot afford to keep expensive corn-belt land in bluegrass. For the average farmer this may be true, but it is almost essential to the breeder of pure-bred live stock. Also the increasing cost and scarcity of farm labor may make it economical to keep some of the land in permanent pasture.

Timothy. — Timothy is more widely grown than any other grass in this country. It may be pastured earlier in the spring than bluegrass, but it does not produce so much growth in the fall. It is neither as palatable nor as valuable a feed as bluegrass. It is, however, better adapted for temporary pasture, as it can be fully established in a single season. For this purpose it should be mixed with clover.

Timothy should be grazed so closely that but few seed stems are thrown up.

The chemical composition of timothy pasture is as follows: water, 61.6 per cent; ash, 2.1 per cent; crude protein, 3.1 per cent; crude fiber, 11.8 per cent; nitrogen-free extract, 20.2 per cent; and fat, 1.2 per cent. As indicated by the chemical composition, timothy has not as high a feeding value as bluegrass. Still, if it contains some clover to make up the deficiency in the protein and ash, it answers very well for a temporary pasture, especially during the spring and summer. It may be used for all classes of livestock. It is less valuable for hogs than for any other class of farm animals.

Canada bluegrass is most abundant in eastern Canada and northeastern United States. It will grow under more adverse conditions than Kentucky bluegrass, which it resembles in appearance and habit of growth. It is not quite as high in feeding value as Kentucky bluegrass, but it is a good substitute for it.

The millets, although little used for pasture, are extensively grown for soiling crops. They are quite valuable when so used.

The sorghums are sometimes used for pasture. Serious trouble and sometimes death often result from cattle or horses eating second-growth sorghum. This also happens sometimes from eating first-growth sorghum. This usually occurs after the growth of the plant has been temporarily checked by severe drought or frost. The difficulty seems to be due to the formation of prussic acid in the plant. Sweet sorghum, kafir corn, milo maize, Sudan grass, and feterita all have the same objection. In general, it is safer not to pasture the second-growth of these crops.

The sorghums are excellent for soiling and are probably used more extensively for this purpose than any other crop in the United States.

Red top, as previously stated, is adapted for growth on poor, wet lowlands. It is more valuable for pasture than for hay.

Orchard grass does well in shady places, as in orchards. It will stand heavy grazing and furnishes pasture very early in the spring and very late in the fall.

FIG. 78. — Brome-grass. (Piper, Forage Plants.)

Bermuda grass is the ordinary non-legume pasture of the South. It is very valuable and nutritious. It is said that one acre of good Bermuda grass will support two head of cattle or ten head of sheep for eight months.

Johnson grass, although used for hay in the South, is not as valuable for pasture, as, like the sorghums, it sometimes contains prussic acid.

Brome grass is the most important pasture grass of the Dakotas and Saskatchewan. It is also used extensively for pasture in Kansas and

Nebraska. It is quite resistant to drought and tramping, furnishes an abundance of pasture both in the early spring and in the late fall, and is very palatable. It is nearly as valuable as bluegrass.

Rye. — Fall-sown rye is sometime used for pasture. It is hardy, grows on poor soils, comes early in the spring and, under optimum conditions, may provide pasture both in the fall and again in the spring. It is often possible to obtain some kind of a crop after the rye, or clover and grass seed may be sown in it in the spring. Rye should be pastured closely in the spring as soon as growth has really started. If it is pastured for only a short time, a good crop of grain often may be harvested from it. Grain should be fed with rye pasture, as it is very succulent and laxative. Although it is not advisable to make a practice of sowing rye for pasture, it is often profitable when other pasture is scarce.

It is especially good before the other pastures come in the early spring for ewes and nursing lambs, and also for sows and pigs. However, it will be noticed in the latter case that any bluegrass in the fence rows will be eaten off clean before the pigs will touch rye, showing that they much prefer the bluegrass. Also, if sheep are allowed other pasture, they will not go back to rye. It often is profitable, especially when rye is badly lodged, to turn in hogs to harvest it when ripe. If milch cows are pastured upon rye, it imparts a bitter flavor to the milk which is quite offensive. Green rye is often used for soiling.

Oats alone are seldom used for pasture. However, as has already been mentioned, oats and peas are often sown together and used for pasture or soiling.

Barley is sometimes sown in the spring and used for pasture in the North.

Wheat is seldom sown for pasture. However, when it becomes so badly lodged that it is impossible to harvest it for the grain, it makes good pasture for hogs. "Hogging down" wheat, however, is quite expensive unless it cannot be harvested in any other way.

Corn is seldom pastured green, although it is used in many systems of soiling.

It is a common custom in the newer parts of the corn-belt to husk the corn in the field, leaving the stalks stand. These

FIG. 79. — Hogging down corn. (Iowa Experiment Station.)

are pastured by turning in cattle, horses, and sheep. Stalk-fields pastured in this way will furnish but little more than a maintenance ration and should be supplemented by other feeds if much growth or fattening is expected. "Corn-stalk disease," a mysterious and usually fatal disease, sometimes attacks animals which are turned into stalk-fields during the fall and early winter. No one seems to know the cause, means of prevention, or cure for "corn-stalk disease." Less frequently it attacks horses and cattle which are fed on cured corn stover or corn fodder. It seems to be more

prevalent when the growth of the corn plant has been prematurely checked by severe drought or early frost. Some authorities believe that its poisonous nature is due to the presence of prussic acid, as in the case of immature, second-growth sorghum. Others believe it to be due to a mold or fungus on the plant. Because of the danger from cornstalk disease, whatever it may be, the author does not recommend the use of stalk pasture for valuable animals.

FIG. 80. — Meadow-fescue. (Piper, Forage Plants.)

On account of the *cost and the scarcity* of farm labor, "hogging down" corn is coming into favor as an economical way of harvesting part of the corn crop. It apparently has been demonstrated that more pounds of pork may be produced from an acre of corn if it is harvested by the hogs themselves than if the grain is husked and fed to them.[1] For the best results, hogs should not be given access to the

[1] See Missouri Bul. 95 and 110, and Iowa Bul. 143.

entire field, but should be limited to that portion of the field which they will clean up in ten days or two weeks. This may be done by means of a movable or temporary fence. Before being turned in, they should be brought gradually to a full-feed of new corn. They should be turned in when the dent has just been formed in the corn kernel. Cowpeas, soybeans, rape, rye, or other forage crops planted in the corn after the last cultivation add considerably to the feeding value. An adjoining pasture of clover or alfalfa is advantageous if there is no legume forage in the cornfield. If no leguminous forage is supplied with the corn, the hogs should receive some tankage, middlings, or linseed meal in addition.

Perennial rye grass is the principal pasture grass of Europe, occupying the same position there as bluegrass holds in the United States. However, it is of little importance in the United States.

Meadow fescue is used some for pasture in Kansas and Nebraska. It is quite palatable and is considered especially valuable for fattening cattle.

CHAPTER XVIII

SILAGE

SILAGE consists of finely cut plants, harvested before maturity while they still contain considerable water, and compressed compactly in a silo and allowed to ferment. During the fermentation a part of the sugars in the plant are broken down, with the formation of organic acids, such as lactic, acetic, and butyric acids and carbon dioxide gas. After a certain amount of these acids have been formed, they act as an antiseptic and prevent further fermentation. The resulting product is a succulent, palatable, nutritious, and cheap feed which may be used to advantage for nearly all classes of livestock.

Silos are of various types. They may be made of wooden staves, of lath and plaster, of brick, of stone, of concrete, of concrete blocks, of concrete staves, of steel, and of vitrified tile. In semiarid parts of the country, a pit is dug in the ground and used as a silo. It is not within the province of this book to discuss the relative merits of the different types of silos. There are, however, three essential features which a good silo should have. (1) The walls of the silo should be impervious to moisture and air. The fundamental principle in the preservation of silage is the retention of moisture within the silage and the exclusion of air. For this reason, the silo wall must be non-porous. Moisture must be prevented from passing out and air from passing

in. (2) The walls of a silo must be strong enough to resist the bursting pressure of the silage which acts outward in all directions as the silage settles. The friction of the silage on the walls and the weight of the material of the walls produce a crushing action which is very great near the bottom of the silo. (3) To permit the silage to settle freely and to prevent the formation of air pockets, the walls should be smooth on the inside and not have shoulders or offsets. Air pockets result in more or less spoiled silage.

There are a number of advantages in using the silo, but the greatest of them is the possibility it affords of utilizing all the corn crop. There was a time when land was cheap and there was an abundance of coarse feed at hand that had little market value. Under these conditions it was not a serious loss if a portion of the corn crop was wasted. At the present time, with both farm lands and feeds high in price, conditions are quite different. When the ears of corn are husked in the ordinary way and the stalks left in the field, from 60 to 70 per cent of the nutritive value of the corn crop is taken with the ears, while 30 to 40 per cent remains with the stalks. It is possible to utilize a small portion of this nutriment by turning stock into the stalk fields in the ordinary manner. However, the benefits derived in this way are comparatively small and often not worth the risk of losing valuable animals from corn-stalk disease.

The next most important advantage of silage is its palatability. A silo not only preserves the succulence of the green fodder but the bacterial fermentations which the fodder undergoes develops large amounts of organic acids and other substances which add greatly to the palatability of the

silage. The feeding of silage in the winter makes it possible to keep the animals in practically the same condition that they are when on pasture in the summer. A good quality of silage is so palatable that many animals will eat it in preference to grain, and cows will eat silage even when on good pasture.

As compared with the cutting, shocking, and husking of the corn, the use of the silo is a distinct saving of labor. When putting corn in the silo it is handled but once and then under the most favorable conditions. That is to say, it is handled in large quantities and with an organized force and under favorable weather conditions. The use of the silo is also a cheap and convenient way of handling large amounts of coarse fodder.

In unpropitious weather, the hay crop may be put in the silo as a means of saving the crop.

Although other crops may be put in the silo, corn is practically the only one so used in the corn-belt. Corn and cowpeas are sometimes used, as the peas add considerable protein to the silage. Clover, alfalfa, cowpeas, soybeans, kafir, sorghum, cannery refuse, beet pulp, etc., are sometimes put in the silo.

Corn silage. — Corn for the silo should not be cut too green. The tendency, until quite recently, has been to cut corn for the silo while it was still in the milk stage. A sweeter silage, containing a higher percentage of nutrients, is obtained by cutting the corn when it is just past the milk stage and the lower leaves of the stalk are beginning to die. If cut too ripe, the desired succulence is lost. If, for any reason, the corn has passed the desired stage, the succulence of the silage may be improved by running a stream of water

through a hose into the silo while it is being filled, or by directing the water into the top of the distributor, where it is knocked into a fine spray and mixed with the silage.

Frosted or soft corn is practically as valuable for silage as sound corn. At the Iowa Station [1] it was found that the husked ears from soft corn made satisfactory silage when ensiled without the stalk and leaves. Thus the silo offers a solution to the soft corn problem.

According to Eckles at the Missouri Experiment Station,[2] the average yield of silage per acre when corn varies in yield from 30 to 100 bushels is as follows:

Yield of Corn Bushels	Yield of Silage Tons
30	6
40	8
50	10
60	12
80	16
100	20

The tonnage of silage per given yield of corn varies, of course, with the locality and the season.

The average chemical composition of corn silage is as follows: water, 73.6 per cent; ash, 2.1 per cent; crude protein, 2.7 per cent; crude fiber, 7.8 per cent; nitrogen-free extract, 12.9 per cent; and fat, 0.9 per cent. Its net energy value is 16.6 therms per 100 pounds. In composition and energy value corn silage resembles green clover except that the latter is considerably higher in crude protein.

It is often said that a part of the feeding value of corn fodder is lost through fermentations which take place in the silo. This is true in part. A part of the protein is

[1] Unpublished results. [2] Bul. 103.

changed to non-protein. Furthermore, some of the starch and sugar is changed to acetic acid (found in vinegar), lactic acid (found in sour milk), butyric acid (found in stale butter), and other organic acids, which, although probably not as high in feeding value as the carbohydrates from which they are formed, add materially to the flavor of the silage. A certain amount of energy is lost from the ensiled corn as heat, liberated during fermentation. These losses of nutrients, however, are certainly not as great as the losses due to weathering occurring in field-cured fodder. The digestibility of the nutrients of corn silage and corn fodder are about the same. The increased consumption of roughage which otherwise is dry and unpalatable makes this the most economical method of handling the corn crop.

Until recently, corn silage has been used primarily as a feed for dairy cattle. Lately, however, it has come into use as a feed for cattle and sheep of all classes and is being used to some extent for horses and mules. In feeding silage one always should bear in mind that it is not a concentrate, but a non-nitrogenous roughage containing a very large amount of water, and, consequently should be properly supplemented with other feeds.

For dairy cows, 25 to 50 pounds of silage per day may be fed, 30 to 40 pounds being a good average. It should be fed so as to remove several inches from the top of the silo every day, particularly in warm weather, in order to prevent unnecessary decay and waste. It should be fed only after milking and any that is uneaten should be removed, as it is liable to impart a disagreeable flavor and odor to the milk. If frozen, it should be allowed to thaw out before feeding. Moldy silage should not be fed. About 5 to 10 per cent more

milk is obtained from one pound of dry substance in the form of silage than from the same amount of dry substance in corn fodder. It should be fed with clover or alfalfa hay and a mixture of concentrates, which should contain linseed meal, cottonseed meal, gluten feed, or some other nitrogenous concentrate.

For Beef Cattle. — There is no roughage which is of more importance to the producer of beef cattle than silage. Just as pasture is almost essential in summer for breeding cattle, so is silage necessary in winter. In fact, experiments now in progress at the Illinois Station seem to indicate that silage may be substituted in large part for pasture in the summer. Corn silage with clover or alfalfa hay will bring the breeding herd through the winter in good shape. Oat straw or corn stover may be used as the dry roughage, if a pound of linseed meal or cottonseed meal is added to the ration.

For fattening cattle, corn silage is one of the most economical feeds if properly used. It produces exceptionally cheap gains in the early part of the feeding period. In feeding silage to fattening cattle they should be fed as much of it as they will consume at the beginning of the feeding period. This should be 40 to 50 pounds per day per 1000 pounds live weight. Most failures in feeding silage to fattening cattle are due to the fact that the feeder started them in on a small amount and gradually increased it. Corn silage may furnish all or only part of the roughage in the ration of fattening steers. In either case, nitrogenous concentrates, such as linseed meal or preferably cottonseed meal, should be fed with corn in addition to the roughage. Fed as the sole roughage, a ton of silage is equal to one-half ton

of clover hay. Corn silage, when properly supplemented, is a more profitable roughage than clover or alfalfa hay. However, the addition of a small amount of dry roughage, such as clover or alfalfa hay or oat straw, to a ration of silage, corn, and cottonseed or linseed meal usually makes the gains more economical. When fed with silage, corn should be shelled, as the cob adds too much indigestible roughage to the ration.

For Sheep. — Corn silage is used by many sheepmen for all classes of sheep. On the other hand, many sheepmen have no use for it. Especial care should be taken not to feed sour, moldy, or frozen silage to sheep. Unlike the feeding of silage to cattle, sheep should be started in on a small quantity of silage (about one-half pound) and the amount gradually increased. Corn silage up to three or four pounds daily with clover or alfalfa hay makes a good winter ration for the breeding ewe up until lambing time, when some concentrates should be fed. Up to two or three pounds daily, it may be used profitably in the ration of fattening lambs and sheep. A ration of corn, corn silage, and clover or alfalfa hay is usually conducive to good gains. If only a small amount of the legume hay is used, protein should be added in the form of linseed meal or cottonseed meal. Oat straw and silage seem to make a very good roughage for fattening wethers. It should be noted that sheep are very susceptible to spoiled silage and great care should be exercised in feeding silage to sheep in warm weather when decomposition is likely to take place.

Horses. — Silage may be successfully fed to horses if the proper precautions are taken in its use. It is of utmost importance that silage fed to horses should be free from mold,

as certain molds which grow on silage are deadly poison to horses and mules. Thus, Rusk and Grindley, at the Illinois Experiment Station,[1] killed an entire lot of five horses in 6 to 22 days by feeding moldy silage. Corn which is to be used for silage for horses should be fairly mature, as immature corn causes a sour silage which is apt to produce colic. It is also unsafe to feed horses frozen silage on account of danger of colic. Horses should be gradually accustomed to silage, and they should not be fed too heavily on it.

The greatest value of silage as a horse feed is to carry work horses during the slack season through the winter and to act as a supplement to pasture during drought. For wintering horses, hay is the only other feed which need be used in the ration, unless a little linseed meal or cottonseed meal is given for the additional protein which it contains. They should be started on about 5 pounds of silage daily per 1000 pounds live weight, the grain and hay being gradually decreased, and the silage increased until, at the end of a month, the ration is made up of 20 pounds of silage and 10 pounds of hay per 1000 pounds live weight. Corn, cottonseed meal, hay, and silage is a profitable ration for fattening draft horses for the market. Not much silage should be used in the ration of work horses, as it is too succulent and too bulky.

For Hogs. — Silage should not be used in the rations of hogs, as it is too bulky.

Clover, alfalfa, cowpeas, and soybeans may be put in the silo. They make a fairly palatable silage which is high in protein. They should be cut at the same time as for

[1] Unpublished results.

hay-making, and care should be taken to pack them thoroughly in the silo. However, it is usually inadvisable to use these crops for silage if they can be made into hay.

Sweet sorghum, ferterita, milo, kafir corn and the other *sorghums are extensively used for silage in the West and* Southwest where the rainfall is insufficient for corn. In palatability and feeding value, they are nearly equal to corn silage. Sorghum should be quite well matured before it is put in the silo or it will make a very sour silage, due to the large amount of sugar present.

Sorghum bagasse, the residue of the cane mills, and the *leaves of the cane* make *a fairly good silage and should not* be wasted.

Cannery refuse, such as corn husks and pea vines, is sometimes put in the silo. The feeding value of such refuse is usually quite low.

Beet pulp sometimes is put in the silo. It makes a valuable silage.

CHAPTER XIX

MISCELLANEOUS ROUGHAGES

Roots. — Under this term are included all plants whose roots, tubers, bulbs, or other underground vegetative parts are used for feed. Roots are very succulent in nature, containing from 85 to 90 per cent or more of water. Although they are usually classed with the roughages, they have a very high nutritive value. Henry [1] states, "Roots may be regarded as watered concentrates high in available energy for the dry matter which they contain . . . a pound of dry matter in roots has the same feeding value as a pound of corn, wheat, barley, or oats." They may be used to advantage with practically all classes of live stock. They are highly relished and have a peculiarly beneficial effect upon the digestion and general thrift of animals. The only objection to their general use is the cost and difficulty of growing, harvesting, and storing them. Inasmuch as corn silage is quite similar in nature and gives nearly as good results, it usually can be substituted for roots in general farm feeding, although the latter are almost absolutely necessary in the rations of show animals.

The most common roots used for stock feeding in this country are mangels (stock beets) and sugar beets. Carrots, rutabagas, turnips, potatoes, Jerusalem artichokes, chufas, and cassava also are used sometimes.

[1] *"Feeds and Feeding," 14th ed., p. 193.*

Mangels or Mangel-wurzels. — The average chemical composition of mangels is as follows: water, 90.9 per cent; ash, 1.1 per cent; crude protein, 1.4 per cent; crude fiber, 0.9 per cent; nitrogen-free extract, 5.5 per cent; and fat, 0.2 per cent. The net energy value is 4.6 therms per 100 pounds. Their actual feeding value, however, is much greater than their chemical composition indicates. They are especially valuable in keeping the digestive system in

FIG. 81. — Mangels. (Cornell Experiment Station.)

good condition. Their most important use is to promote growth in young animals and to stimulate milk production. If fed in too large quantities, they are liable to cause scouring. They are commonly sliced before feeding.

Milk cows and beef cattle may be fed 20 to 30 pounds per day. Young calves may be fed two or three pounds per day, the amount being increased as they grow older. In England as much as 100 pounds per day are fed cattle which are being fattened. Mangels are not usually fed to horses, but there is no apparent reason why a few pounds daily

would not be beneficial. They may be fed to brood sows in large quantities in winter and to fattening hogs in limited quantities. Hogs may be turned in on a field of mangels and allowed to harvest the crop if they are fed grain in addition. Mangels may be used for feeding sheep. If fed in large quantities for extended periods of time, they are liable to cause renal and urinary calculi, sometimes resulting in the death of the animal so affected. Feeding them in large quantities to pregnant ewes may result in lambs with so-called "water-bellies."

FIG. 82. — Sugar beet. (Livingston, *Field Crop Production*.)

Sugar Beets. — Sugar beets have a higher feeling value, pound for pound, for fattening animals than mangels, as they contain considerably more dry matter, especially in the form of sugar. On account of the increased cost of production, however, it is usually more profitable for the farmer to grow mangels. For growing animals and for milk production, they are no more valuable than mangels, although, owing to their high sugar content, they are usually better relished. The cull beets of the sugar factories are quite valuable. Sugar beets are sliced and fed in the same manner as mangels.

Carrots are used especially for breeding horses, show horses, and horses which are not at hard work. They are

too laxative to be fed in quantity to driving horses. They may also be used for milk cows and other stock, but are usually considered too expensive for these purposes.

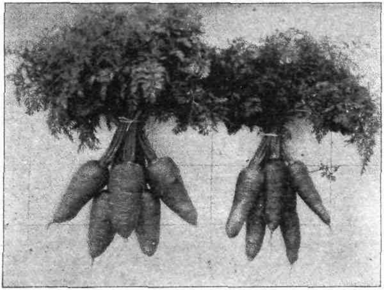

FIG. 83. — Carrots. (Cornell Experiment Station.)

Rutabagas or Swedes are grown extensively in Great Britain and in Canada. Sheep prefer them to all other roots. They may be used for all classes of farm animals.

Turnips are often grown as a catch crop. They are quite watery and are not as satisfactory for stockfeeding as some of the other roots. They are used mainly for sheep, but may be fed to cattle.

Potatoes. — Undersized potatoes are often used for feed, particularly for hogs. They should be cooked and fed with dry concentrates. The water in which they are cooked should be discarded as it may be poisonous.

Jerusalem artichokes are sometimes used for stock feeding, especially for hogs. The crop is permitted to grow until

killed by frost, when hogs are turned in and allowed to harvest the tubers which the plant produces.

Chufas are grown to a certain extent in the South and the tubers harvested by hogs.

Cassava also is grown somewhat in the extreme South, the roots sometimes being used for stock feed.

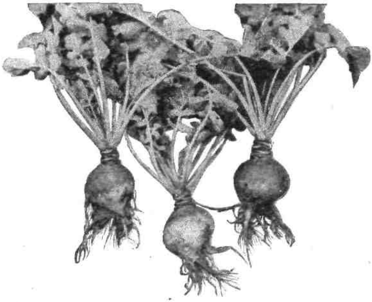

Fig. 84. — Rutabagas. (Cornell Experiment Station.)

Peat is often sprinkled or soaked in molasses and sold under some trade name at a fancy price. Much gross misrepresentation is made in advertising such feeds, claiming that they have a very high nutritive value, that they prevent and cure disease, and other unwarranted statements. As a matter of fact, peat has a nutritive value about half that of straw. Finely ground peat is also used sometimes as an adulterant of tankage.

Alfalfa meal is made by grinding alfalfa hay. It is often

sprinkled with molasses. Alfalfa meal properly made has a very high feeding value, being nearly equal to bran. However, a large part of the alfalfa meal on the market is made from alfalfa chaff or the lower grades of alfalfa hay so that its feeding value is usually lower than its cost. When such feeds are used the farmer should either prepare them himself or make certain that the manufacturer is using good alfalfa hay in the manufacture of his product. Even then he should remember that alfalfa meal is no higher in feeding value than the alfalfa hay and molasses of which it is made.

FIG. 85. — Cassava. (Duggar, Southern Field Crops.)

Rape is not a grass but belongs to the mustard family. It stores its nutriment in the leaves and stems somewhat like cabbage. It may be sown at any time from early spring until August and is ready for use in 8 to 12 weeks. It is a cool weather plant and does better in the early spring or late fall. If sown early in the spring and not pastured too heavily, it may be pastured again in the fall. It is used extensively for soiling.

Although cattle may be profitably pastured on rape, its greatest use is for sheep and swine. Sheep upon rape pasture and receiving no grain make very fair gains. It is more valuable as sheep pasture than bluegrass. Access

to clover or bluegrass pasture will be beneficial, however, and will aid in preventing bloat. As a forage for hogs, rape ranks a little below alfalfa and red clover, but higher than bluegrass, soy beans, cowpeas, and rye.[1] It should be supplemented by clover pasture and one-half to two-thirds full-feed of corn, or by corn and tankage, corn and linseed meal, or corn and middlings.

Oftentimes white hogs if allowed to run in wet rape will develop bad sores on their backs and sides. Animals on

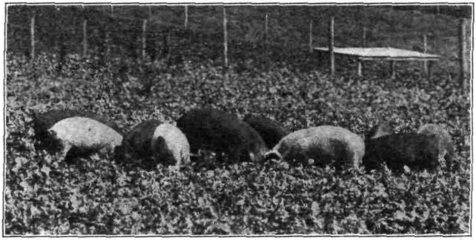

FIG. 86. — Hogs in rape. (Missouri Experiment Station.)

rape have a craving for salt, which should be supplied in larger amounts than under ordinary conditions.

Rape should be used more generally in the corn-belt as a temporary pasture, especially for pork production. It is one of the most valuable of the non-legume pasture and soiling crops.

Cabbage is sometimes used as a roughage for sheep, especially for show animals. It is used in England for milch cows to a certain extent.

[1] Ohio Exp. Sta. Bul. 242; Missouri Exp. Sta. Bul. 110.

Kohlrabi is a member of the mustard family. It has a short, thick stem. It is sometimes used as a substitute for

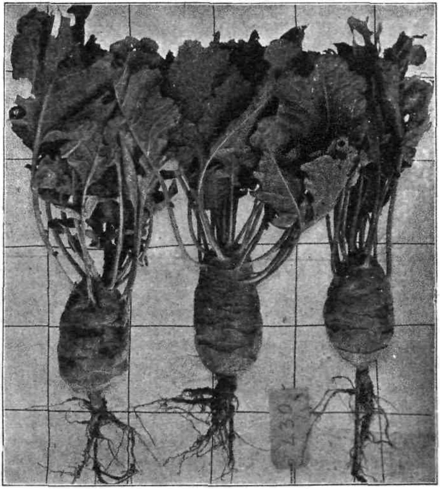

FIG. 87. — Kohlrabi. (Cornell Experiment Station.)

the root crops in the Middle West as it is more easily harvested. It also may be pastured.

Kale is another member of the mustard family. It is used in England and France as a soiling crop. In the United States it is grown in New England and along the

north Pacific coast. It is fed as a soiling crop, particularly to dairy cows. It should not be fed during milking as it may taint the milk.

Beet tops have considerable feed value. They should be fed in limited amounts with dry roughage.

Pumpkins are sometimes planted with the corn and used for stockfeeding. They are usually fed to milk cows and sometimes to hogs. Their feeding value may be compared with that of roots.

Apple pomace, remaining from the manufacture of cider, is sometimes used for stockfeeding. It is usually dumped in large piles near the cider press. The rotten portion on the outside is removed and the fermented pomace used. A dairyman in northern Ohio informs the author that he has used apple pomace for several years for his milk cows with satisfactory results. He claims that it is as valuable as corn silage and may be substituted for it in the dairy ration.

CHAPTER XX

THE EFFICIENCY OF RATIONS

WE have learned that a maintenance ration is one which is just sufficient to support the vital functions of the animal when it is at rest, without any loss or gain of body tissue. If an excess of feed above the requirements for maintenance is given the animal, there may be some production, *i.e.* the animal may do work, or it may produce milk, or meat, or wool, or some other product which has an economic value. However, not all the excess feed above the maintenance requirement can be recovered by the animal in the form of some useful product. As a matter of fact, a large part of it is wasted by the animal in some form or other. It already has been shown that the horse can recover in the form of work only about one-third of the net energy of the ration. Similarly, meat-producing and dairy animals can recover only a fraction of their ration in the form of meat or milk.

The efficiency of a ration is its value expressed in terms of the product for which the animal is fed. In other words, the efficiency of a ration expresses the amount of feed required to produce a given result, such as a pound of gain, or a pound of milk. The efficiency of the ration must not be confused with the economy of the ration as expressed in dollars and cents. As a matter of fact, the ration which is most efficient is often uneconomical, owing to its high

cost. Thus in practical feeding operations, not only the efficiency but also the cost of the rations must be considered. In general, efficiency depends largely upon two general classes of factors, one class concerning the ration itself, and the other class concerning the animal which consumes the ration.

Among the factors relating to the ration itself are the following: the physical composition, chemical composition, digestibility, amount, and preparation of the ration. The principal factors concerning the animal are: the species, type and grade, age, capacity, temperament, and previous treatment of the animal, the length of the fattening period, and the temperature and other climatic conditions.

The physical composition of the ration, *i.e.* the nature of the feedingstuffs which make up the ration, is a large factor in determining the efficiency. It is commonly known that certain combinations of feedingstuffs are more efficient for certain purposes than certain other combinations. For example, a ration of corn and clover hay is more efficient for producing gains than a ration of barley and clover hay, although they both contain practically the same amounts of digestible protein, total nutriment, and net energy. A large part of the work of animal husbandry investigators has consisted of a comparison of different rations in order to determine what combinations of feedingstuffs are most efficient for different purposes. Obviously, the stockfeeder always should endeavor to feed a ration which will make the production as efficient and economical as possible.

The chemical composition of the ration determines its efficiency to a large extent. A ration which is deficient in any of its nutrients, or a ration which contains an excess of

any nutrient is not as efficient as one which supplies the proper amounts and proportions of the nutrients, *i.e.* a balanced ration. Thus a ration of corn, linseed meal, and clover hay is more efficient for beef production than one of corn and timothy hay, largely because the former ration supplies more nearly the proper proportions of the different nutrients.

The digestibility of the ration has a marked effect upon its efficiency. Obviously the more digestible the ration is, the greater is its efficiency. Thus a ration consisting largely of the more digestible concentrates is more efficient than one consisting largely of the less digestible roughages as the undigested part of the ration has no value to the animal body. Of course, the relative prices of concentrates and roughages also must be considered in formulating the ration, as this will determine to a large extent their proportions in the ration.

The Amount of the Ration. — When one considers that a certain amount of feed is always necessary for maintenance, it would seem that the larger the amount fed above maintenance the more efficient would be the gains. On the other hand, as has been stated, a full-feed ration containing a fairly large proportion of roughage to concentrates is not digested as thoroughly as a smaller ration. In an experiment at the Illinois Experiment Station [1] by Mumford, Grindley, Emmett, and Bull with 4 lots of four 2-year-old steers each, all lots were fed corn and clover hay for 22 weeks, after which time linseed meal was introduced into the ration. The feeding period extended over 37 weeks. One lot received as much feed as they

[1] Unpublished data.

would eat readily; another was given a little more than a maintenance ration; another, an amount of feed equal to the maintenance ration plus one-third of the difference between the maintenance and full-feed rations; and another an amount equal to the maintenance ration plus two-thirds of the difference between the maintenance and full-feed rations. The average daily gains, the amounts of feed to produce a pound of gain, and the amounts of dry substance to produce a pound of gain were as follows:

Lot	Average Daily Gain	Feed per Pound of Gain		Dry Substance per Pound of Gain
		Concentrates	Hay	
	Lb.	*Lb.*	*Lb.*	*Lb.*
Full feed	2.13	8.25	2.75	9.63
Two-thirds feed . .	1.79	8.13	2.63	9.40
One-third feed . . .	1.32	8.22	2.66	9.51
Maintenance . . .	*0.70*	*10.07*	*3.29*	*11.61*

The results of this experiment indicate that a ration slightly above maintenance is less efficient for producing gains than larger rations. However, there was little or no difference in the efficiency of the full feed, two-thirds feed, and one-third feed rations for the production of gains.

It is of importance to note, however, that when animals are being fattened for the market, the degree of finish also must be considered. As an animal possessing a high degree of finish is ordinarily worth more per pound than an animal possessing a lower degree of finish, it usually will be more economical from the market standpoint to feed as large a ration as possible without throwing the animal off feed, in order to attain a high degree of finish.

In feeding dairy cows, the ration should be as large as possible without causing digestive derangements, if it is all used for milk production. However, if part of the ration is used for the storage of body fat (as indicated by a considerable gain in weight, especially in the mature animal), a smaller ration will prove more efficient. (See page 144.)

The preparation of the ration often is assumed to have considerable influence upon the efficiency of production. We already have seen that in most cases grinding, crushing, cooking, soaking, fermenting, and chaffing feed does not materially increase its digestibility but, on the contrary, in certain instances it decreases it. The preparation of the feed has practically the same effect upon the efficiency of a ration as it has upon its digestibility.

Mumford, at the Illinois Station,[1] concluded that for fattening steers, whole corn when fed with clover hay was more efficient than shelled corn and that, when hogs followed the steers, shelled corn was as efficient as ground corn. However, when feeding silage as a large part of the roughage of the ration, it is more efficient if the corn is shelled. When cattle are not followed by hogs, it is usually more efficient to grind the corn. Also it is usually economical to grind the grain for heavy producing dairy cows and for horses at very hard work. From the results of elaborate experiments by Kennedy and Robbins at the Iowa Experiment Station[2] upon the preparation of corn for hogs, it was concluded that hogs weighing under 200 pounds made the most economical gains when their corn was fed in the form of dry ear corn, and that hogs weighing over 200 pounds made the most economical gains when their corn

[1] Bul. 103. [2] Bul. 106.

was shelled and soaked in water 12 hours before feeding. King,[1] at the Indiana Experiment Station, concluded that with young hogs there is practically no difference in the results obtained from ear corn and ground corn. However, after the hogs reach a weight of about 150 pounds, ground corn is slightly more efficient. Grinding usually increases the efficiency of wheat, barley, rye, emmer, and oats for beef cattle, for dairy cattle, for hogs, and, with the exception of oats, for horses. Grain never should be ground for sheep except in the case of very young lambs. It is a common saying among sheepmen that a sheep that cannot grind its own grain is not worth keeping.

Cooking does not increase the efficiency of the ration except in the case of potatoes and beans when fed to swine. On the contrary, cooking usually decreases the efficiency of the ration. The same is true of steaming the ration.

Soaking corn may be advantageous, especially when it becomes dried out, hard, and flinty. All grain that is difficult of mastication should be either soaked or ground.

Chaffed (or finely cut) hay or straw may be more efficient than whole hay or straw under certain conditions, as for horses at very hard work, or for heavy-producing milch cows; but, in general, the practice is not recommended. Also there is no advantage in shredding corn stover, except that it is stored and handled more easily and makes better bedding.

The species of animal has a marked influence upon the efficiency of the ration. Thus cattle ordinarily require about 8 pounds of concentrates and 5 pounds of roughage to produce one pound of gain, sheep require about 5 pounds of concentrates and 5 pounds of roughage to produce one

[1] Proceedings of the American Society of Animal Production for 1913.

pound of gain, while hogs require only about 5 pounds of concentrates to produce one pound of gain. Table 25, which is made up from results compiled by Jordan,[1] shows the comparative efficiency of different species of farm animals to convert their feed into marketable products and into edible dry substance.

TABLE 25.—PRODUCT FROM 100 POUNDS OF DIGESTIBLE ORGANIC MATTER

ANIMAL	PRODUCT	TOTAL AMOUNT	EDIBLE DRY SUBSTANCE
		Lb.	*Lb.*
Dairy cow	milk	139	18
Dairy cow	cheese	15	9
Dairy cow	butter	6	5
Hog	live weight	30	—
Hog	dressed carcass	25	16
Fowl	eggs	20	5
Fowl	live weight	20	—
Fowl	dressed carcass	16	4
Sheep	live weight	14	—
Sheep	dressed carcass	7	3
Steer	live weight	13	—
Steer	dressed carcass	8	3

This table shows that the dairy cow and the hog give the greatest returns per 100 pounds of digestible organic matter, *i.e.*, they utilize their rations most efficiently as far as the production of human food is concerned. The fowl ranks next, with the sheep and steer last. It is of interest to note that the returns, as a rule, vary directly with the amount of labor expended. Labor is a large factor in the production of dairy products, while it is reduced to a minimum

[1] "The Feeding of Animals," p. 405.

in case of fattening steers. It should be noted also that the hog and fowl, although quite efficient in the utilization of their rations, cannot use large quantities of roughage, while the sheep and steer, although less efficient, can utilize large quantities of roughage which, otherwise, would be wasted ordinarily as far as its feeding value is concerned. Furthermore, hogs and poultry are quite susceptible to disease, while sheep are subject to the ravages of dogs.

The type and grade of animals have considerable influence upon the efficiency of the ration. One does not select cows of pronounced beef type for the production of dairy products, as they do not convert their feed into milk as efficiently as do cows of the dairy type. On the other hand, one does not select steers of dairy conformation for fattening. Mumford at the Illinois Station [1] compared feeder steers of different types and market grades with the following results:

Grade of Steers	Beef Produced per Bushel of Corn	Digestible Dry Substance to Produce One Pound of Gain
	Lb.	*Lb.*
Fancy	9.74	9.95
Choice	7.97	12.09
Good	7.99	12.08
Medium	7.45	13.05
Common	8.13	12.00
Inferior	7.61	12.93

These results indicate, other things being equal, that the better grades of animals are more efficient than the poorer grades.

[1] Bul. 90.

Armsby and Fries at the Pennsylvania Station[1] found that a pure-bred Angus steer utilized his ration more efficiently than a scrub steer, primarily because the maintenance requirement of the pure-bred steer was less, leaving more energy available to produce flesh.

Further, the mutton type sheep is a more efficient producer of meat than the fine wool type. On the other hand, the latter is a more efficient producer of wool.

Fowls of the meat type are more efficient producers of meat than those of the egg type, while the latter are more efficient producers of eggs than the former.

The conformation of the horse and the kind of work he is doing have an effect on the efficiency. Thus, horses of the draft type are most efficient for work of heavy draft, light harness horses for work of locomotion, and saddle horses for carrying a weight.

The age of the animal has considerable influence upon the efficiency of gains. Other things being equal, the younger the animal, the greater is the efficiency. Older animals usually make larger daily gains than younger ones, but they are not made as efficiently as in the case of the younger animals. This is shown quite clearly in a compilation made by Henry and Morrison[2] from over 500 pig feeding trials, involving more than 2200 animals. A modification of their table is as follows:

[1] Bul. 105. [2] "Feeds and Feeding," p. 569.

TABLE 26. — RELATION OF WEIGHT OF HOGS TO EFFICIENCY OF GAINS

WEIGHT OF PIGS	AVERAGE FEED PER DAY	AVERAGE FEED PER 100 LB. LIVE WEIGHT	AVERAGE GAIN PER DAY	FEED PER 100 LB. GAIN
Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
15 to 50	2.2	6.0	0.8	293
50 to 100	3.4	4.3	0.8	400
100 to 150	4.8	3.8	1.1	437
150 to 200	5.9	3.5	1.2	482
200 to 250	6.6	2.9	1.3	498
250 to 300	7.4	2.7	1.5	511
300 to 350	7.5	2.4	1.4	535

As shown by the table, production became less efficient as the pigs became heavier and, presumably, older. Similar results are shown in a compilation of cattle feeding trials made by the author. The average of 33 feeding trials with 2-year-old steers showed a net energy consumption of 9.1 therms for every pound of gain, while the average of 4 feeding trials with calves and yearlings showed a net energy consumption of 6.3 therms for every pound of gain.

Armsby [1] presents the following figures as representing the amounts of net energy above maintenance to produce a pound of gain in cattle.

AGE OF CATTLE	NET ENERGY
Months	*Therms*
3	1.50
6	1.75
12	2.00
18	2.50
24	2.75
30	3.00
mature	3.50

[1] U. S. Dept. of Agr. Farmers' Bul. 346.

In another compilation by the author of results of experiments upon fattening cattle, 8 lots of 3-year old steers required an average of 9.4 pounds of digestible organic matter to produce a pound of gain, 56 lots of 2-year-old steers required 8.4 pounds of digestible organic matter, while 27 lots of calves and yearlings required only 6.7 pounds of digestible organic matter to produce a pound of gain.

After three years of experimentation with calves, yearlings, and two-year-olds Skinner and Cochel, at the Purdue Experiment Station,[1] concluded that the rate of gain and the cost of gain increase with the increased age of cattle.

It might be well to note, however, that the younger the animal is, the more care it will require, and the longer the time necessary to finish the animal. Also the younger animal requires a larger proportion of expensive concentrates in its ration than does the older animal.

The Capacity of the Animal. — The capacity of the animal in most cases has considerable influence upon the efficiency. If the animal has a small capacity, it can consume only a comparatively small amount of feed above the maintenance requirement which is available for production. This makes the production expensive. On the other hand, if the animal has a large capacity, considerable more feed will be available for production. To illustrate this point, we will assume that a steer requires 12 pounds of feed daily for maintenance, and 6 pounds of feed above maintenance to produce a pound of gain. If he eats only 18 pounds of feed and makes a gain of one pound, it will have taken 18 pounds of feed to produce a pound of gain. However, if he consumes 24 pounds of feed and makes a gain of 2 pounds

[1] Purdue Bul. 146.

per day, it will have taken 12 pounds of feed to produce a pound of gain; while if he consumes 30 pounds of feed and makes a gain of 3 pounds, it will have taken only 10 pounds of feed to produce a pound of gain. Thus the animal having the larger capacity can utilize the ration more efficiently, *as a larger proportion of the ration is available for productive purposes.* In general, animals of small capacity are expensive and inefficient machines for the transformation of feed into meat or milk.

The temperament of the animal has considerable influence upon the efficiency of the ration. Armsby [1] and Fries have shown that the maintenance requirement of a nervous, restless steer was 17 per cent greater than the maintenance requirement of a quiet, phlegmatic steer of the same age and weight. He found also that the mere *act of standing increased the maintenance requirement 20 per cent.* Hence, fattening stock and dairy cows should receive no more exercise than necessary for their general health, and pains should be taken to remove all causes of excitement from them, such as females in heat, vicious dogs, etc. They should be well bedded in order to induce them to lie down as much as possible. It is important from an economic as well as from a humanitarian standpoint that one should treat the farm animals with kindness.

The previous treatment of the animal may have considerable influence upon the efficiency. It is a matter of common knowledge among stockmen that a steer which is maintained through the winter on roughage alone will make more efficient gains in the spring when put on pasture than a steer which is given a more liberal ration through the

[1] Penn. Agr. Exp. Sta. Bul. 105.

winter. However, in case of the young growing animal, growth may be so checked that the animal will never attain the broad, deep form of the typical meat animal, but will be tall, narrow, and upstanding. It is also common knowledge among feeders that range cattle, because of not being previously accustomed to grain, are not as efficient meat producers in the feed lot as native cattle which have been accustomed to grain.

Dietrich [1] presents results of experiments with pigs which indicate that the maintenance requirement may be lowered by fasting the animal or by feeding only a small ration. He claims that the animal makes more efficient gains after such treatment.

In an experiment at the Illinois Experiment Station [2] by Mumford, Grindley, Hall, Emmett, Bull, and Allison with steers, it was found that steers which had been on a maintenance ration for some time made more efficient gains when put on full feed than steers which had been on a full-feed ration.

Length of the Fattening Period. — Other conditions being equal, the longer the fattening period, the larger is the amount of feed required to produce a pound of gain. As only the excess of feed above the maintenance requirement can be used for production, it is apparent that the longer the fattening period, the greater the amount of feed used by the animal for maintenance and, consequently, the less the amount of feed available to produce gains. For example, if a steer requiring 12 pounds of feed daily for maintenance can be fattened satisfactorily in 90 days, it will take less feed than if 168 days are taken to fatten him,

[1] *Ill. Agr. Exp. Sta. Bul. 163.* [2] *Unpublished data.*

because in the shorter feeding period the feeder will save the feed required to maintain the steer for 78 days, *i.e.*, 936 pounds of feed.

The Kansas Experiment Station [1] found the grain required for 100 pounds of gain in the case of fattening steers was as follows:

	Grain for 100 Pounds Gain
	Lb.
Up to 56 days	730
Up to 84 days	807
Up to 112 days	840
Up to 140 days	901
Up to 168 days	927
Up to 182 days	1000

The length of the fattening period usually will depend to a large extent upon four factors: (1) the feedingstuffs available, (2) the age of the animal, (3) the grade of the animal, and (4) the condition of the animal.

When it is desired to feed a large proportion of roughage to concentrates, the fattening process is slow and a longer time is required to finish the animal than when a highly concentrated ration is fed. The relative cost of concentrates and roughage should be considered in this connection. Younger animals usually require a longer time to finish than do more mature ones. Low grade feeders finish more quickly than do those of high grade at the same weight and in the same condition, because they usually are older. They can never reach a high degree of finish, however. Animals in good condition ordinarily require less time to finish than those in poor condition.

[1] Bul. 34.

Temperature and Climatic Conditions. — Climatic conditions may have considerable influence upon the efficiency with which an animal utilizes its ration. It has been stated that in ordinary winter weather horses, hogs, and perhaps dairy cattle, unless properly sheltered, must oxidize a part of their ration to keep the body warm. In extremely cold weather, or in damp, windy, cold weather, or when given large amounts of very cold water to drink, cattle and sheep must do the same. Thus, the amount of the ration available for production is lessened and the ration is less efficient for productive purposes, *i.e.*, it requires more feed to produce the same result. Also in very hot weather, especially if flies are bad, the animal becomes less efficient and the amount of production from a given amount of feed is decreased.

CHAPTER XXI

THE FERTILIZING VALUES OF FEEDINGSTUFFS

In addition to the direct products of feeding, such as meat or milk, the feeder also has the manure as a more or less valuable by-product. It is not only of interest but also of practical value to know the fertilizing value of manure from the various feedingstuffs, and the factors which may affect its value.

Ordinarily four mineral elements must be supplied or made available to conserve the fertility of the soil; viz., nitrogen, potassium, phosphorus, and calcium, all of which are contained to a certain extent in the excreta of our farm animals. However, inasmuch as the amount of calcium in manure is small, only the nitrogen, potassium, and phosphorus will be considered in this connection. In addition to the mineral elements, a certain amount of organic matter must be present in the soil to assist in making some of the mineral elements available and to improve the physical condition of the soil.

The principal source of the fertilizing constituents of the excreta is, of course, the feed of the animal. It has already been shown that the animal does not digest all the ration, any undigested material passing off in the feces. It also was stated that, if a surplus of protein is fed above the demands of the body for repair, growth, and milk production, the excess is used for energy or fat production. In either

case the nitrogen of the protein molecule is split off and excreted through the urine. Also small amounts of mineral matter, including potassium and phosphorus, are excreted in the urine, while larger amounts are excreted in the feces. In other words, all the nitrogen, potassium, and phosphorus of the ration which is not permanently stored in the body (or used for milk production) is ultimately excreted and may be returned to the soil for fertilizer. Also, all the undigested organic matter of the feces may be returned to the soil to supply the humus.

The amount of manure, both liquid and solid, is quite variable for the different farm animals under different conditions. According to Van Slyke[1] the amounts of manure produced for 1000 pounds of live weight by the different farm animals in one year are as follows:

Animal	Dung	Urine	Total
	Lb.	*Lb.*	*Lb.*
Horse	14,400	3,600	18,000
Cow	19,000	8,000	27,000
Hog	18,300	12,200	30,500
Sheep	8,300	4,200	12,500
Hen	8,500		8,500

Of primary importance in this connection is a knowledge of the proportion of each fertilizing constituent of the feed which may be recovered in the manure. At the Illinois Experiment Station,[2] Mumford, Grindley, Emmett, and Bull fed eight two-year-old steers for a period of 37 weeks. The consumption and excretion of nitrogen and phosphorus

[1] "Fertilizers and Crops," p. 294.

[2] Unpublished data.

were determined throughout the entire experiment. The ration and the average percentages of the total nitrogen and phosphorus contained in the ration which were excreted in the manure (feces and urine) were as follows:

Week	Ration	Percent N. Excreted	Percent P. Excreted
1– 5	Clover hay, 1 part; corn, 1 part .	81.7	92.1
8–13	Clover hay, 1 part; corn, 3 parts.	86.5	95.8
17–22	Clover hay, 1 part; corn, 5 parts.	86.7	84.9
25–37	Clover hay, 1 part; corn, 4 parts; linseed meal, 1 part	90.4	80.7
1–37	Average	87.4	86.1

During a digestion experiment at the Illinois Experiment Station [1] with six milch cows for 15 days, all of the nitrogen of the ration was excreted, 80 per cent being in the dung and urine and 20 per cent in the milk. Of the phosphorus consumed, about 73 per cent was excreted in the feces and urine, and 22 per cent in the milk. Of the potassium, 76 per cent was excreted in the feces and urine, and 14 per cent in the milk.

The Pennsylvania Station [2] ran a digestion experiment on two milk cows for 50 days. Eighty-five per cent of the nitrogen of the ration, 71 per cent of the phosphorus, and 91 per cent of the potassium were recovered in the manure.

In experiments by Grindley and associates with pigs at the Illinois Station [3] it was found that about 90 per cent of the nitrogen of the ration is returned in the feces and urine.

[1] Unpublished data.
[2] Annual Report, 1899–1900.
[3] Unpublished data.

Laws and Gilbert at Rothamsted [1] obtained the following results:

Animal	Per cent of Ash Constituents of Feed in Manure	Per cent of Nitrogen of Feed in Manure
Horse at rest	100	100
Horse at work	100	100
Fat steer (mature)	98	96
Fat sheep (mature)	96	96
Fat pig	96	85
Milch cow	90	75
Calf	46	31

Although these results are not conclusive by any means, yet it seems safe to assume that with fairly mature fattening or work animals about 90 per cent of the nitrogen, 75 per cent of the phosphorus, and 90 per cent of the potassium may be recovered in the manure. In case of milch cows not so much is recovered in the manure because some is excreted in the milk.

The proportion of the organic matter of the ration which is recovered in the manure depends, of course, upon the amount of the organic matter digested. Thus feeds which are quite digestible will produce a manure low in organic matter, while feeds which are less digestible will produce more organic matter in the manure. Ordinarily about one-fourth of the organic matter of the ration is recovered in the manure. In experiments with steers by Mumford, Grindley, Emmett, and Bull at the Illinois Station,[2] 26.6 per cent of the organic matter of the feed was recovered in the manure.

[1] Warington, "Chemistry of the Farm," p. 214.

[2] Unpublished data.

Factors Affecting the Value of the Manure. — There are various factors affecting the value of the manure, among which may be mentioned the following: the feeds in the ration, the age of the animal, the species of animal, loss of the liquid manure, and losses by leaching and fermentation.

Feeds in the Ration. — Of course the more nitrogen, phosphorus, and potassium there are in the ration the more there will be in the excreta and, consequently, the more valuable is the manure. Thus manure from a ration of corn and timothy hay is not nearly as valuable as manure from a ration of corn, cottonseed meal, and alfalfa hay. In general, the use of feeds high in nitrogen and mineral matter greatly increases the value of the manure.

The age of the animal has an effect upon the value of the manure. The young animal will store considerable of the nitrogen, phosphorus, and potassium of its ration in the form of new tissue or growth, while the mature animal excretes all that is not used for maintenance. Also the manure from a milch cow is less valuable than the manure from a beef animal on the same ration because the milch cow excretes a part of the nitrogen, phosphorus, and potassium in her milk, while the beef animal excretes all above the requirements for maintenance and growth in the manure.

The species of animal has considerable effect upon the value of the manure. According to Van Slyke[1] the manure of the different farm animals contains the following percentages of nitrogen, phosphorus, and potassium:

[1] "Fertilizers and Crops," p. 291.

Animal	Water	Nitrogen	Phosphorus	Potassium
	Per cent	*Per cent*	*Per cent*	*Per cent*
Horse	78	0.70	0.11	0.45
Cow	86	0.60	0.07	0.37
Pig	87	0.50	0.15	0.33
Sheep	68	0.95	0.15	0.83

Thus sheep manure is the most valuable. Horse manure ranks second, while cow manure ranks third, and pig manure last.

Loss of Liquid Manure. — If the liquid manure or urine is not saved, the manure loses a large part of its fertilizing value. In case of the Illinois experiment with eight steers already mentioned, 49 per cent of the nitrogen excreted was in the urine, and 51 per cent in the feces. Practically all of the phosphorus was excreted in the dung. In the Illinois and Pennsylvania experiments with milch cows already noted, about one-third of the nitrogen consumed was excreted in the dung and one-half in the urine. Most of the phosphorus was excreted in the dung, and a larger part of the potassium was excreted in the urine.

Van Slyke [1] presents the following table showing the relative amounts of plant-food constituents in the dung and urine:

	Total Nitrogen Excreted		Total Phosphorus Excreted		Total Potassium Excreted	
	In Dung Per Cent	In Urine Per Cent	In Dung Per Cent	In Urine Per Cent	In Dung Per Cent	In Urine Per Cent
Horse	62	38	100	0	56	44
Cow	49	51	100	0	15	85
Pig	67	33	88	12	57	43
Sheep . . .	52	48	95	5	30	70

[1] "Fertilizers and Crops," p. 296.

Thus, unless the urine is retained either in a cistern, by a concrete floor with curbing, by plenty of bedding, or unless the animal is on pasture, about half of the fertilizing value of the manure is lost.

Losses by Leaching and Fermentation. — The loss of the more soluble fertilizing constituents by leaching and fermentation is important. The amount washed out by rains may be considerable, especially if the barnyard is not paved or if it is located on the side of a hill. Experiments at the Cornell Experiment Station found that horse manure exposed to the weather from four to six months lost 40 to 60 per cent of its value due to leaching and fermenting. At the Ohio Station it was found that after exposure to the weather for three months steer manure had lost 28 per cent of its nitrogen, 14 per cent of its phosphorus, and 58 per cent of its potassium. In this connection Van Slyke,[1] makes the following statement: "Taking into consideration both the amount and availability of the plant-food leached from stable manure, it is not an exaggeration to say that two-thirds of the plant food value is leached from much of the stable manure used on American farms."

In addition to losses by leaching, much nitrogen may be lost from stored manure in the form of ammonia or free nitrogen, due to fermentation and decomposition. These losses are especially large if the manure is dry and loose. Thus horse and sheep manures are more liable to losses by fermentation than cow and pig manures, as the latter manures are moister and more compact than the former. In storing manure the farmer can obviate much of the loss due to fermentation by keeping the manure moist and compact. Even

[1] "Fertilizers and Crops," p. 306.

then probably about 15 or 20 per cent of the nitrogen will be lost. However, if no precautions are taken, fully 50 per cent of the nitrogen may be lost by fermentation.

Thus in order to get the most value from the manure, it should be hauled to the field and spread as soon as possible after it is produced, or it should be allowed to accumulate in the stalls or in covered sheds in compact and moist condition, sufficient bedding being used to keep the animals clean, and then hauled to the fields at convenient intervals. In no case should it be allowed to heat and ferment before being spread if its full value is to be secured. In live-stock farming the rotation should be so planned that there is always a place to haul and spread manure as soon as possible after it is produced.

The Commercial Values of Feeds as Fertilizers. — Most of us do not think of our ordinary feedingstuffs as having a commercial value as fertilizers. However, as a matter of fact, the lower grades of tankage are often applied directly to the land as a fertilizer, while in the South cottonseed meal is often used as a fertilizer. Ordinarily the stock-farmer of the corn-belt does not apply the feeds directly to the soil but he first obtains their feeding value by feeding them to his animals and then applies the manure to the soil, thus obtaining both their nutritive value and from 80 to 90 per cent of their fertilizing value. Inasmuch as all feedingstuffs have a certain fertilizing value, it is of interest and value to know just what some of the common feeds are worth as fertilizers after their value as feed has been obtained by the animal. We have seen that about 90 per cent of the nitrogen, 90 per cent of the potassium, and 75 per cent of the phosphorus of the ration is recovered in the manure. Know-

ing the amounts of these elements in the feeds, one may multiply them by the per cent of each recovered in the manure and obtain the amount of fertilizing constituents. Then multiplying the amount of each by the market price of that constituent and adding all together gives the fertilizing value of the feed when fed to farm animals. This, of course, does not take into consideration the value of the organic matter of the manure as a source of humus in the soil. Assuming nitrogen as worth 15 cents per pound, phosphorus, 10 cents per pound, and potassium, 6 cents per pound, which is about what one generally has to pay for these constituents in commercial fertilizers, the ordinary feedingstuffs, after passing through the animals, have the following values as fertilizers:

TABLE 27.—VALUE OF FERTILIZING ELEMENTS IN MANURE FROM FEEDINGSTUFFS

	VALUE PER 100 LB.	VALUE PER BU.	VALUE PER TON
Corn	$0.26	$0.15	—
Oats	0.28	0.09	—
Wheat	0.33	—	$9.80
Soybeans	0.80	0.48	—
Tankage	1.55	—	31.00
Linseed meal	0.74	—	14.80
Cottonseed meal	1.01	—	20.20
Wheat bran	0.50	—	10.00
Wheat middlings	0.49	—	9.80
Clover hay	0.40	—	8.00
Alfalfa hay	0.42	—	8.40
Timothy hay	0.11	—	2.20
Oat straw	0.16	—	3.20
Corn stover	0.14	—	2.80

In buying or selling feeds the fertilizing values should be considered. Thus if one buys a ton of cottonseed meal for \$35.00, in reality the feed costs him only \$14.80, because the manure from it has a value of \$20.20. The man who pays \$2.00 per ton to have oat straw baled, sells it for \$4.00 per ton, and hauls it to the market, loses the feeding value of the straw, the time and labor of hauling, and \$1.20 in cash, because it will cost him \$3.20 to buy commercial fertilizers to replace the fertilizing value of the manure which the straw would make if fed on the farm. Thus, in selling feeds, one should consider how much it will cost to restore the fertility removed from the farm by the crop sold.

In general, instead of selling off a large part of the grain and roughage from the farm and buying " complete " commercial fertilizers to maintain the fertility of the land, it will be better to follow a good system of crop rotation and feed the crops on the farm, thus retaining a large amount of their fertility. If nitrogenous concentrates are purchased and fed on the farm and the manure carefully conserved, it is probable that the feeder will return to the land more fertility than he removes in his crops, and the expenditure for commercial fertilizers will be reduced to a minimum.

CHAPTER XXII

THE VALUATION OF FEEDINGSTUFFS

HAVING seen that most feeders of the corn-belt must buy nitrogenous concentrates in order to properly balance their rations, the question arises, what feed or feeds should he buy? This will depend upon the effect the feed will have upon the animal and its products, upon the cost of the feed, and upon the fertilizing value of the manure resulting from the feed. The nutritive values of the different feeds have already been discussed. So having decided upon a number of feeds which will be satisfactory for the purpose desired, the feeder must select the ones which will prove the most *economical*. This of course will depend upon the *relative prices* of the feeds.

There are no standard prices for the digestible protein, carbohydrates, and fats of feedingstuffs, so one cannot calculate their relative values from their chemical composition as in the case of commercial fertilizers. In fact no entirely satisfactory method of comparing the relative economy of different feedingstuffs has yet been devised. In general, one should compare concentrates with concentrates, or roughages with roughages, upon their content of digestible protein and their content of digestible nutriment, *i.e.* digestible protein, plus digestible carbohydrates, plus digestible fat multiplied by two and one-quarter.

For example, it is desired to know whether cottonseed meal at $30.00 per ton is more economical than linseed meal

$35.00 per ton. Calculating the digestible protein and total nutriment in 100 pounds of each feed, and the cost of 100 pounds of feed, we get the following:

	Digestible Protein	Total Nutriment	Cost
	Lb.	*Lb.*	
100 lb. cottonseed meal . . .	37.6	80.6	$1.50
100 lb. linseed meal	30.2	77.7	$1.75

Therefore,

	Digestible Protein	Total Nutriment
	Lb.	*Lb.*
$1.00 worth cottonseed meal contains . .	25.1	53.7
$1.00 worth linseed meal contains . . .	17.3	44.4

Thus the cottonseed meal at these prices furnishes more protein and more total nutriment per dollar invested than linseed meal.

Although this method of comparison will give good results for many comparisons of the concentrates which are similar to each other, yet when one compares dissimilar concentrates, complications often arise. For example, assuming that tankage cost $50.00 per ton and middlings $30.00 per ton, we have the following comparison:

	Digestible Protein	Total Nutriment	Cost
	Lb.	*Lb.*	
100 lb. tankage	50.1	76.2	$2.50
100 lb. middling	16.9	79.7	$1.50

Therefore,

	Digestible Protein	Total Nutriment
	Lb.	*Lb.*
$1.00 worth tankage contains	20.0	31.9
$1.00 worth middlings contains	11.3	53.1

From this calculation one could not determine which feed is the more economical.

In such instances, it will be necessary to calculate the cost of the ration when one of the feeds is used and compare it with the cost of the ration when the other feed is used. It also will be necessary to know the prices of the other feeds used in the ration. Returning to the example, we will assume that ear corn is worth 50 cents per bushel, and that the feeder wishes to feed 100-pound fattening shotes. According to the Wolff-Lehmann standard, a ration consisting of 2 pounds of shelled corn and 2 pounds of middlings will fulfill the requirements of a 100-pound pig. This ration will cost at the assumed prices for corn and middlings, 4.8 cents per day. Also a ration consisting of 3½ pounds of corn and ½ pound of tankage will satisfactorily fulfill the requirements. The cost of this ration is 4.4 cents per day. Thus, at these prices, the tankage is slightly more economical than the middlings. In this particular instance it probably would pay to buy both feeds for the sake of the variety.

In comparing a concentrate with a roughage, it is better to compare them on a basis of their content of digestible protein and net energy rather than on their content of digestible protein and total nutriment. The reason for this is that the net energy values do not include the energy ex-

pended in digestion, and thus are more accurate in comparing feeds differing greatly in the amount of energy expended in their digestion. For example, 100 pounds of corn and 100 pounds of alfalfa hay contain 84.3 and 53.0 pounds of total nutriment respectively. In other words, alfalfa hay contains nearly two-thirds as much total nutriment as the same amount of corn. However, 100 pounds of corn contain 88.8 therms of net energy, while the same amount of alfalfa hay contains 34.4 therms, or only about one-third as much as the corn. The difference, as previously stated, is due to the larger amount of energy expended in digestion of the hay.

It should be remembered that the comparisons between concentrates and roughages may not always be as accurate by any means as when one compares similar feeds. However, by using his practical knowledge and common sense the feeder can usually determine the most economical combinations of feed to use.

In general, whenever there is doubt as to which feed is most economical, the stock-feeder should calculate the cost of several rations, using his home-grown feeds as their basis and trying the effect of different supplements upon the cost of the rations. However, it is not exactly fair to use the current market prices as the values of the farm-grown feeds, unless it costs nothing in time and labor to market them. One should deduct from their value at the market a reasonable allowance for hauling them to market. On the other hand, one also should make some allowance for the time and labor expended in hauling purchased feed to the feed lots.

APPENDIX

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
GRAINS AND SEEDS						
Cereals	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Dent corn	10.6	1.5	10.3	2.2	70.4	5.0
Flint corn	11.3	1.4	10.5	1.7	70.1	5.0
Soft corn	31.1	0.9	7.4	1.3	55.7	3.6
Corn meal	11.8	1.4	9.8	2.4	70.5	4.1
Corn and cob meal	11.0	1.4	8.9	6.7	68.4	3.6
Wheat	10.5	1.8	11.9	1.8	71.9	2.1
Rye	11.6	1.9	10.6	1.7	72.5	1.7
Oats	11.0	3.0	11.8	9.5	59.7	5.0
Barley	12.0	2.5	11.4	5.7	66.6	1.8
Emmer (spelt)	8.0	3.9	11.5	11.1	62.9	2.2
Rice	12.4	0.4	7.4	0.2	79.2	0.4
Buckwheat	12.6	2.0	10.0	8.7	64.5	2.2
Kafir grain	12.3	1.9	12.3	2.2	68.2	3.1
Milo grain	11.2	1.6	11.2	2.2	70.6	2.8
Feterita grain	10.5	2.0	12.1	2.4	70.3	2.7
Durra grain	11.5	2.0	9.0	3.6	70.1	3.8
Shallu grain	10.7	1.7	12.4	1.7	70.1	3.4
Kaoliang grain	10.9	1.9	10.5	1.7	70.9	4.1
Sorghum grain	12.8	2.1	9.1	2.6	69.8	3.6
Millet	12.0	2.6	11.1	7.7	62.9	3.7
Legumes						
Cowpea	11.9	3.4	23.5	3.8	55.7	1.7
Horse bean	11.3	3.8	26.6	7.2	50.1	1.0
Field pea	10.5	2.6	20.2	5.6	57.8	1.1
Peanut (with hull)	6.6	2.6	23.2	18.4	14.2	35.0
Peanut (without hull)	7.5	2.4	27.9	3.0	16.6	42.6
Soybean	8.7	5.4	36.3	3.9	27.7	18.0
Velvet bean	11.7	2.6	20.8	7.5	51.0	6.4

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
GRAINS AND SEEDS (Continued)						
Oil-bearing Seeds	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Cottonseed	9.1	4.0	19.6	18.9	28.3	20.1
Flaxseed	9.2	4.3	22.6	7.1	23.2	33.7
Sunflower seed	8.6	2.6	16.3	29.9	21.4	21.2
CEREAL BY-PRODUCTS						
Hominy feed	10.0	2.8	10.8	4.9	64.6	6.9
Gluten feed	8.5	1.9	25.9	7.2	53.3	3.2
Gluten meal	9.5	1.0	36.0	2.1	49.1	2.3
Germ oilmeal	9.0	2.7	22.7	9.3	45.9	10.4
Corn bran	8.7	1.5	9.8	11.2	62.6	6.2
Corn cobs	10.7	1.4	2.4	30.1	54.9	0.5
Distillers' grains, dried	5.8	2.8	30.9	10.7	39.2	10.6
Distillers' grains, wet	75.7	1.0	5.4	3.8	12.5	1.6
Wheat flour	11.5	0.5	11.4	0.2	75.4	1.0
Red dog flour	9.7	3.5	19.5	2.8	59.3	5.2
Flour wheat middlings	10.0	3.2	18.8	3.3	59.9	4.8
Shorts	10.0	4.3	17.8	7.0	55.9	5.0
Wheat bran	10.0	6.2	16.1	10.0	53.3	4.4
Wheat feed (shorts and bran)	10.0	5.3	16.9	8.1	55.2	4.5
Wheat screenings	11.6	2.9	12.5	6.9	63.1	3.0
Rye middlings	11.0	3.3	14.8	3.8	64.4	2.7
Rye bran	11.6	3.6	14.7	3.5	63.8	2.8
Rye feed (shorts and bran)	9.1	3.9	15.1	4.0	64.6	3.2
Oat middlings	9.0	2.3	15.8	2.4	64.3	6.2
Oat bran	6.6	6.1	12.2	18.3	52.1	4.7
Oat dust	6.7	7.0	12.6	18.7	49.8	5.2
Oat hulls	7.3	6.7	3.3	29.7	52.1	1.0
Malt	7.5	2.4	9.5	9.0	69.1	2.5
Malt sprouts	11.0	5.9	26.4	12.3	43.1	1.3
Brewers' grains, dried	8.0	3.4	24.1	13.0	44.8	6.7
Brewers' grains, wet	75.7	1.0	5.4	3.8	12.5	1.6

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
CEREAL BY-PRODUCTS (Continued)						
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Rice polish	10.2	5.5	12.3	2.5	60.2	9.3
Rice bran	10.2	10.6	12.6	13.5	41.3	11.8
Rice meal	12.6	10.2	12.0	8.0	45.2	12.0
Buckwheat middlings	11.5	4.5	27.5	4.2	45.3	7.0
Buckwheat bran	11.5	4.5	24.8	11.7	40.8	6.7
Buckwheat feed	10.0	3.2	15.9	22.0	44.8	4.1
Buckwheat hulls	13.2	2.2	4.6	43.5	35.3	1.1
OIL BY-PRODUCTS						
Cottonseed meal, choice	7.0	6.7	44.6	6.5	25.2	10.0
Cottonseed meal, prime	7.1	5.8	40.0	10.4	29.3	7.4
Cottonseed meal, good	7.2	5.8	37.7	11.8	30.1	7.5
Cold pressed cottonseed	8.4	4.0	26.6	25.8	28.4	7.9
Cottonseed feed	8.8	4.1	23.1	22.6	36.5	4.9
Cottonseed hulls	11.1	2.8	4.2	46.3	33.4	2.2
Linseed meal, O. P.	8.5	5.2	34.3	8.5	36.4	7.1
Linseed meal, N. P.	9.0	5.6	37.4	8.9	36.4	2.7
Flax feed	9.5	7.3	16.6	11.2	41.2	14.2
Flax screenings	8.0	6.0	16.8	13.7	40.9	14.6
Peanut cake	10.7	4.9	47.6	5.1	23.7	8.0
Soybean cake	8.0	5.4	41.6	4.8	31.6	8.6
Coconut meal	10.5	5.2	21.4	11.7	42.7	8.5
Palmnut cake	9.7	4.0	17.7	23.8	36.2	8.6
Rapeseed cake	10.0	7.7	33.1	11.1	27.9	10.2
Sesame cake	9.5	10.7	39.8	6.8	20.6	12.6
Sunflower cake	9.2	6.3	39.4	11.8	20.7	12.6
Hempseed cake	12.0	8.0	31.8	20.2	18.0	10.0
PACKINGHOUSE BY-PRODUCTS						
Dried blood	8.5	4.7	84.4	—	—	2.5
Fish meal	10.8	29.2	48.4	—	—	11.6

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
PACKINGHOUSE BY-PRODUCTS (Continued)						
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Pork cracklings	5.3	2.0	53.9	—	—	36.8
Bone meal	8.0	64.4	23.9	—	3.4	0.3
Tankage, good grade	7.0	15.0	61.0	3.5	3.5	10.0
MISCELLANEOUS CONCENTRATES						
Beet pulp, wet	89.9	0.4	1.0	2.2	6.3	0.2
Beet pulp, dry	10.0	3.3	9.1	18.6	58.3	0.7
Beet pulp, molasses	8.0	5.8	9.9	14.1	61.7	0.5
Cocoa shells	5.0	10.3	15.4	16.5	49.8	3.0
Molasses, beet	20.8	10.6	9.1	—	59.5	—
Molasses, cane	26.0	6.2	3.2	—	64.6	—
Molasses feed	11.0	6.8	13.3	10.8	53.0	5.1
Molasses-alfalfa feed	11.5	9.1	12.1	17.1	47.7	1.5
Cow's milk, whole	87.2	0.7	3.6	—	4.9	3.7
Cow's milk, skim	90.5	0.8	3.6	—	5.1	0.1
Buttermilk	90.4	0.8	3.6	—	5.0	0.2
Whey	93.8	0.4	0.6	—	5.1	0.1
HAYS						
Legumes						
Alfalfa	9.1	8.4	14.7	28.4	35.8	1.9
Alfalfa (brown)	20.0	8.8	12.9	21.4	33.8	3.1
Alfalfa meal	9.0	8.0	13.2	32.7	35.8	1.3
Alfalfa leaves	6.8	13.6	22.3	12.8	41.1	3.4
Beggar weed	9.0	8.4	15.2	27.6	37.5	2.3
Clover, alsike	15.0	9.7	14.0	23.1	36.1	2.1
Clover, bur	10.4	10.7	18.0	26.3	31.4	3.1
Clover, crimson	9.6	8.6	15.2	27.2	36.6	2.8
Clover, mammoth	15.0	8.2	13.1	24.4	37.6	1.7
Clover, red	15.0	7.7	13.3	24.3	37.2	2.5
Clover, red (brown)	14.5	8.6	13.8	23.7	36.8	2.6
Clover, sweet	9.0	7.3	14.4	27.3	39.9	2.1

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
HAYS (Continued)						
Legumes	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Clover, white	9.7	8.3	15.7	24.1	39.3	2.9
Cowpea	10.7	8.5	18.6	20.1	39.2	2.9
Lespedeza or Japan clover	11.0	8.5	13.8	24.0	39.0	3.7
Lupine	16.0	4.5	15.3	19.0	43.2	2.0
Pea, Canada field	15.0	6.7	13.7	24.7	37.6	2.3
Peanut vine	7.6	10.8	10.7	23.6	42.7	4.6
Sanfoin	16.5	7.3	13.2	22.0	38.5	2.5
Serradella	9.2	7.2	15.2	21.6	44.2	2.6
Soybean	11.3	7.2	15.4	22.3	38.6	5.2
Velvet bean	7.2	7.4	16.4	27.5	38.4	3.1
Vetch	13.2	7.5	17.7	23.3	35.9	2.3
Grasses						
Bermuda grass	8.9	7.9	7.2	24.9	49.4	1.8
Bluegrass	14.0	6.4	7.7	30.5	39.7	1.7
Brome grass	6.7	7.7	8.7	31.5	44.4	1.0
Buffalo grass	7.6	11.3	7.9	26.1	45.3	1.8
Fescue, meadow	14.0	7.1	5.8	32.2	39.3	1.6
Johnson grass	9.7	7.1	7.2	30.0	44.1	1.9
Millet	10.2	7.9	7.7	27.7	49.0	2.3
Mixed grasses	14.0	5.3	7.9	28.7	43.2	2.2
Orchard grass	14.0	5.9	8.3	29.9	39.3	2.6
Prairie hay	13.3	13.8	5.5	26.4	43.4	2.5
Red top	8.9	5.2	7.9	28.6	47.5	1.9
Rye grass, Italian	8.5	6.9	7.5	30.5	45.0	1.7
Sudan grass	3.5	5.6	4.7	35.6	49.3	1.3
Salt marsh	15.0	6.6	6.1	23.4	46.8	2.1
Timothy, all analyses	13.2	4.4	5.9	29.0	45.0	2.5
Timothy, full bloom	15.0	4.5	6.0	29.6	41.9	3.0
Timothy, late bloom	14.2	4.4	5.7	28.1	44.6	3.0
Timothy, nearly ripe	14.1	3.9	5.0	31.1	43.7	2.2
Barley hay	10.6	5.3	9.3	23.6	48.7	2.5
Emmer hay	7.7	9.3	10.0	33.6	37.3	2.1
Oat hay	13.4	6.0	7.7	27.8	42.2	2.9
Rye hay	8.0	4.9	6.8	37.6	40.7	2.0

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
FODDERS AND STOVERS						
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Corn fodder	18.3	4.0	6.7	17.0	52.1	1.8
Corn fodder, high in water	40.2	3.7	4.5	15.3	34.7	1.6
Corn stover	17.0	6.3	5.6	28.0	42.1	1.0
Corn stover, high in water	40.0	3.9	4.6	20.6	30.1	0.8
Kafir fodder	8.4	11.8	13.1	22.4	40.2	4.1
Kafir stover	19.2	8.0	4.8	26.8	39.6	1.6
Milo fodder	8.9	11.5	13.0	19.5	41.6	5.0
Sorghum fodder	8.9	5.7	5.4	28.5	48.8	2.8
Sorghum fodder, high in water	28.0	4.0	4.0	24.0	37.0	3.0
Durra fodder	10.0	5.2	6.4	24.1	51.5	2.8
Broom corn fodder	9.4	5.7	3.9	36.8	42.4	1.8
STRAWS						
Barley straw	14.2	5.7	3.5	36.0	39.1	1.5
Buckwheat straw	9.9	5.5	5.2	43.0	35.1	1.3
Millet straw	15.0	6.3	4.8	35.2	36.4	2.3
Oat straw	9.2	5.1	4.0	37.0	42.4	2.3
Rice straw	6.6	14.9	4.1	31.6	41.4	1.5
Rye straw	7.1	3.2	3.0	38.9	46.6	1.2
Wheat straw	9.6	4.2	3.4	38.1	43.4	1.3
Cowpea straw	8.5	5.4	6.8	44.5	33.6	1.2
Soybean straw	10.1	5.8	4.6	40.4	37.4	1.7
Clover straw	16.0	5.7	9.1	44.6	22.8	1.8
PASTURE OR FORAGE, AND SOILING CROPS						
Legumes						
Alfalfa	71.8	2.7	4.8	7.4	12.3	1.0
Beggarweed	72.8	3.2	4.2	7.5	11.8	0.5
Clover, alsike	74.8	2.0	3.9	7.4	11.0	0.9
Clover, bur	79.3	2.3	5.1	3.9	7.7	1.7

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
PASTURE OR FORAGE, AND SOILING CROPS (Continued)						
Legumes	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Clover, crimson	80.9	1.7	3.1	5.2	8.4	0.7
Clover, mammoth	80.0	1.9	3.0	5.8	8.9	0.4
Clover, red	70.8	2.1	4.4	8.1	13.5	1.1
Clover, sweet	80.0	1.9	3.8	6.3	7.4	0.6
Clover, white	81.5	2.1	4.4	4.3	6.9	0.8
Cowpea	85.0	2.0	2.8	3.5	6.3	0.4
Horsebean	85.1	1.4	3.0	4.3	5.7	0.5
Lupine	83.1	1.0	3.2	5.3	7.0	0.4
Pea, Canada field	85.0	1.3	3.2	4.3	5.8	0.4
Lespedeza	63.4	3.5	6.7	10.7	14.7	1.0
Sanfoin	75.0	2.1	4.4	6.0	11.6	0.9
Serradella	79.5	3.2	2.7	5.4	8.6	0.7
Soybean	75.1	2.6	4.0	6.7	10.6	1.0
Velvet bean	82.1	2.0	3.5	5.1	6.6	0.7
Vetch	82.0	2.5	4.2	5.5	5.4	0.4
Grasses						
Bermuda grass	66.8	2.3	3.0	8.0	18.9	1.0
Bluegrass, Kentucky	65.1	2.8	4.1	9.1	17.6	1.3
Bluegrass, Canada	66.8	2.6	3.0	10.2	16.2	1.2
Brome grass	65.5	3.0	4.4	9.5	16.1	1.5
Fescue, meadow	69.9	1.8	2.4	10.8	14.3	0.8
Johnson grass	74.0	1.4	2.2	8.9	13.2	0.3
Millet	71.1	1.7	3.1	9.2	14.2	0.7
Orchard grass	70.0	2.1	2.9	10.4	13.7	0.9
Rye grass, Italian	73.2	2.5	3.1	6.8	13.3	1.3
Red top	65.3	2.3	2.8	11.0	17.7	0.9
Tall oat grass	69.5	2.0	2.4	9.4	15.8	0.9
Timothy	61.6	2.1	3.1	11.8	20.2	1.2
Barley	75.0	2.1	3.2	7.4	11.6	0.7
Oats	75.0	2.0	3.5	7.5	11.2	0.8
Rye	76.6	1.8	2.6	9.6	8.8	0.6
Dent corn	80.0	1.0	1.6	4.6	12.4	0.4

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
PASTURE OR FORAGE, AND SOILING CROPS (Continued)						
Grasses	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Flint corn	79.8	1.1	2.0	4.3	12.1	0.7
Sweet corn, roasting ears	79.1	1.3	1.9	4.4	12.8	0.5
Sweet corn, ears removed	80.0	1.2	1.4	4.9	12.0	0.5
Kafir	73.0	2.0	2.3	6.9	15.1	0.7
Milo	83.2	1.5	1.7	5.5	7.5	0.6
Sweet Sorghum	80.0	1.0	1.2	6.2	11.2	0.4
Durra	85.9	1.3	1.7	4.7	6.0	0.4
Broom corn	77.1	1.7	2.0	8.6	10.1	0.5
Sugar cane	84.2	1.1	1.2	4.0	9.0	0.5
SILAGE						
Corn, well matured	73.7	1.6	2.2	6.5	15.0	0.9
Corn, immature	80.0	1.1	1.7	5.4	11.1	0.7
Corn, frosted	74.5	1.7	2.3	6.0	14.6	0.9
Corn, ears removed	80.4	1.4	1.4	6.3	9.8	0.7
Durra	79.7	1.9	1.2	7.0	9.5	0.7
Kafir	69.2	2.5	1.8	9.9	15.5	1.1
Sorghum	76.1	1.1	1.8	6.4	14.3	0.3
Alfalfa	75.4	2.9	3.5	8.2	8.6	1.4
Apple pomace	79.7	1.0	1.6	4.3	12.0	1.4
Clover	72.0	2.6	3.7	8.4	12.1	1.2
Corn and soybean	76.0	2.3	2.7	7.3	10.9	0.8
Cowpea	78.0	2.2	3.1	6.3	9.4	1.0
Soybean	74.2	2.8	4.1	9.7	6.9	2.2
Sugar beet tops	77.0	7.4	2.4	3.4	9.1	0.7
ROOTS						
Artichoke	78.0	1.8	2.4	0.9	16.8	0.1
Beet, common	88.5	1.0	1.5	0.9	8.0	0.1
Beet, sugar	86.7	0.8	1.5	0.9	9.9	0.1

TABLE 28. AVERAGE COMPOSITION OF FEEDINGSTUFFS (Continued)

FEEDINGSTUFF	WATER	ASH	CRUDE PROTEIN	CARBOHYDRATES		FAT
				Crude Fiber	N-free Extract	
ROOTS (Continued)						
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Carrot	88.6	1.0	1.1	1.3	7.6	0.4
Mangel	91.2	1.0	1.4	0.8	5.4	0.2
Potato	78.9	1.0	2.1	0.6	17.3	0.1
Rutabaga	88.6	1.2	1.2	1.3	7.5	0.2
Turnip	90.6	0.8	1.3	1.2	5.9	0.2
MISCELLANEOUS ROUGHAGES						
Apple	80.7	0.4	0.7	1.2	16.6	0.4
Apple pomace	76.7	0.5	1.4	3.9	16.2	1.3
Cabbage	90.5	1.4	2.4	1.5	3.9	0.4
Kale	89.7	1.9	2.2	1.2	4.5	0.5
Kohlrabi	86.5	1.6	2.8	1.6	7.1	0.4
Melon, pie or stock	94.5	0.4	0.8	1.2	2.9	0.2
Pumpkin	90.9	0.5	1.3	1.7	5.2	0.4
Rape	84.5	2.0	2.3	2.6	8.4	0.5
Sugar beet leaves	83.8	4.8	2.3	1.6	7.4	0.4

TABLE 29. — PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP[1]

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
GRAINS AND SEEDS				
Cereals	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Dent corn	89.4	7.6	67.5	4.6
Flint corn	88.7	7.8	66.9	4.6
Soft corn	68.9	5.5	53.1	3.3
Corn meal	88.2	7.3	67.7	3.8

[1] Feedingstuffs for hogs are given in Table 30, page 352.

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
GRAINS AND SEEDS (Continued)				
	Per cent	*Per cent*	*Per cent*	*Per cent*
Cereals				
Corn and cob meal	89.0	4.6	63.2	3.0
Wheat	89.5	8.8	68.0	1.5
Rye	88.4	8.9	68.3	1.1
Oats	89.0	9.2	51.7	4.3
Barley	88.0	8.9	64.5	1.4
Emmer (spelt)	92.0	9.2	63.1	1.9
Rice	87.6	4.6	73.0	0.4
Buckwheat	87.4	7.5	51.1	2.2
Kafir grain	87.7	10.0	63.9	2.4
Milo grain	88.8	9.2	66.2	2.1
Feterita grain	89.5	9.8	66.0	2.1
Durra grain	88.5	7.3	66.5	2.9
Shallu grain	89.3	10.0	65.4	2.6
Kaoliang grain	89.1	8.5	66.1	3.1
Sorghum grain	87.2	7.4	65.6	2.7
Millet	88.0	7.2	58.3	2.8
Legumes				
Cowpea	88.1	19.3	54.2	1.3
Horse bean	88.7	23.1	49.8	0.8
Field pea	89.5	16.8	55.8	0.6
Peanut (with hull)	93.4	19.5	25.3	28.7
Peanut (without hull)	92.5	23.4	14.5	34.9
Soybean	91.3	30.5	23.4	14.8
Velvet bean	88.3	17.5	43.3	5.2
Oil-Bearing Seeds				
Cottonseed	90.9	13.3	28.5	17.5
Flaxseed	90.8	20.6	17.1	29.0
Sunflower seed	91.4	11.1	33.4	18.4

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
CEREAL BY-PRODUCTS				
	Per cent	*Per cent*	*Per cent*	*Per cent*
Hominy feed	90.0	7.1	61.8	6.3
Gluten feed	91.5	22.0	52.4	2.7
Gluten meal	90.5	30.6	45.4	2.1
Germ oilmeal	91.0	16.6	43.0	10.0
Corn bran	91.3	5.9	58.1	5.0
Corn cobs	89.3	0.5	46.6	0.2
Distillers' grains, dried	94.2	22.6	42.0	10.1
Distillers' grains, wet	24.3	3.9	13.7	1.5
Wheat flour	88.5	10.0	66.5	0.9
Red dog flour	90.3	17.2	53.2	4.5
Flour wheat middlings	90.0	16.5	53.9	4.1
Shorts	90.0	13.7	45.7	4.4
Wheat bran	90.0	12.6	41.5	3.0
Wheat feed (shorts and bran)	90.0	13.0	44.9	3.9
Wheat screenings	88.4	9.0	51.1	2.6
Rye middlings	89.0	11.8	60.0	2.4
Rye bran	88.4	11.8	59.2	2.5
Rye feed (shorts and bran)	90.9	12.1	60.4	2.9
Oat middlings	91.0	12.6	55.9	5.8
Oat bran	93.4	9.8	53.3	4.4
Oat dust	93.3	10.1	51.5	4.8
Oat hulls	92.7	1.7	45.4	0.8
Malt	92.5	7.6	64.6	1.9
Malt sprouts	89.0	20.3	45.2	1.1
Brewers' grains, dried	92.0	19.5	31.9	6.0
Brewers' grains, wet	24.3	4.4	9.0	1.4
Rice polish	89.8	8.2	55.5	7.6
Rice bran	89.8	8.2	36.0	9.1
Rice meal	87.4	7.4	48.9	10.9
Buckwheat middlings	88.5	23.4	37.6	6.2
Buckwheat bran	88.5	11.7	27.4	3.8

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
OIL BY-PRODUCTS				
	Per cent	*Per cent*	*Per cent*	*Per cent*
Cottonseed meal, choice	93.0	37.5	21.3	9.5
Cottonseed meal, prime	92.9	33.6	25.8	7.0
Cottonseed meal, good	92.8	31.7	27.0	7.1
Cold pressed cottonseed	91.6	21.5	32.8	7.6
Cottonseed feed	91.2	13.4	32.5	4.4
Cottonseed hulls	88.9	0.3	33.2	1.7
Linseed meal, O. P.	91.5	30.5	33.2	6.3
Linseed meal, N. P.	91.0	32.2	38.2	2.6
Flax feed	90.5	14.8	38.5	12.6
Flax screenings	92.0	15.0	39.7	13.0
Peanut cake	89.3	42.8	20.4	7.2
Soybean cake	92.0	38.3	36.4	5.8
Coconut meal	89.5	16.7	41.4	8.2
Palmnut cake	90.3	15.0	45.1	8.3
Hempseed cake	88.0	23.9	11.9	9.0
Rapeseed cake	90.0	27.4	23.2	8.1
Sesame cake	90.5	35.8	13.6	11.3
Sunflower cake	90.8	33.5	18.2	11.1
PACKINGHOUSE BY-PRODUCTS				
Dried blood	91.5	70.9	—	2.4
Fish meal	89.2	37.8	—	11.6
Tankage, good grade	93.0	56.7	—	9.8
MISCELLANEOUS CONCENTRATES				
Beet pulp, wet	10.1	0.5	7.1	0.1
Beet pulp, dry	90.0	4.7	63.8	0.5
Beet pulp, molasses	92.0	6.3	67.9	0.4
Cocoa shells	95.0	1.7	44.8	3.0
Molasses, beet	79.2	2.9	53.6	—

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
MISCELLANEOUS CONCENTRATES (Continued)	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Molasses, cane	74.0	1.0	58.1	—
Molasses, feed	89.0	4.1	47.3	4.6
Molasses-alfalfa feed	88.5	5.6	46.2	1.4
Cow's milk, whole	12.8	3.6	4.9	3.7
Cow's milk, skim	9.5	3.6	5.1	0.1
Buttermilk	9.6	3.6	5.0	0.2
Whey	6.2	0.6	5.1	0.1
HAYS				
Legumes				
Alfalfa	90.9	10.4	38.0	0.7
Alfalfa (brown)	80.0	9.0	28.2	1.6
Alfalfa meal	91.0	9.8	40.8	0.5
Alfalfa leaves	93.2	15.8	35.1	1.3
Beggar weed	91.0	11.4	36.4	0.7
Clover, alsike	85.0	9.2	35.4	0.8
Clover, bur	89.6	14.6	40.7	1.5
Clover, crimson	90.4	10.5	36.6	1.2
Clover, mammoth	85.0	7.7	38.0	1.0
Clover, red	85.0	7.7	37.3	1.4
Clover, red (brown)	85.5	8.9	36.4	1.3
Clover, sweet	91.0	10.8	38.0	0.7
Clover, white	90.3	11.5	42.2	1.5
Cowpea	89.3	12.6	36.1	1.1
Lespedeza or Japan clover	89.0	8.1	38.7	2.1
Lupine	84.0	11.5	43.0	1.1
Pea, Canada field	85.0	9.3	37.3	0.9
Peanut vine	92.4	7.7	43.0	3.7
Sanfoin	83.5	9.2	36.4	1.6
Serradella	90.8	11.4	38.6	1.7
Soybean	88.7	10.9	40.2	1.5
Velvet bean	92.8	12.0	40.3	1.4
Vetch	86.8	12.9	39.0	1.5

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
HAYS (Continued)				
Grasses	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Bermuda grass	91.1	3.7	38.1	0.8
Bluegrass	86.0	4.4	44.3	0.9
Brome grass	93.3	4.4	47.0	0.4
Buffalo grass	92.4	4.3	43.1	0.8
Fescue	86.0	3.0	44.8	0.9
Johnson grass	90.3	3.2	45.2	0.9
Millet	89.8	4.6	51.6	1.4
Mixed grasses	86.0	4.5	44.6	1.1
Orchard grass	86.0	5.0	40.2	1.4
Prairie hay	86.7	3.3	38.3	1.0
Red top	91.1	4.9	47.3	1.0
Salt marsh	85.0	2.7	38.6	0.7
Timothy, all analyses	86.8	2.8	42.4	1.2
Timothy, full bloom	85.0	3.4	43.3	1.4
Timothy, late bloom	85.8	2.5	39.2	1.5
Timothy, nearly ripe	85.9	2.1	40.1	1.1
Barley hay	.89.4	6.0	45.3	1.0
Emmer hay	92.3	6.5	44.3	0.9
Oat hay	86.6	4.2	38.1	1.8
Rye hay	92.0	3.7	42.4	1.2
FODDERS AND STOVERS				
Corn fodder	81.7	3.0	48.7	1.3
Corn fodder, high in water	59.8	2.0	34.9	1.1
Corn stover	83.0	2.1	43.3	0.6
Corn stover, high in water	60.0	1.7	31.4	0.5
Kafir fodder	91.6	6.0	40.3	2.5
Kafir stover	80.8	1.6	41.8	1.2
Milo fodder	91.1	2.0	35.3	3.1
Sorghum fodder	91.1	2.1	48.1	1.8

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
FODDERS AND STOVERS (Continued)				
	Per cent	*Per cent*	*Per cent*	*Per cent*
Sorghum fodder, high in water	72.0	1.5	37.9	1.9
Durra fodder	90.0	2.9	49.0	1.7
Broom corn fodder	90.6	1.8	50.5	1.1
STRAWS				
Barley straw	85.8	0.7	41.3	0.6
Oat straw	90.8	1.2	38.7	0.8
Rice straw	93.4	0.9	37.6	0.4
Rye straw	92.9	0.6	40.5	0.4
Wheat straw	90.4	0.4	36.3	0.4
Cowpea straw	91.5	3.4	39.1	0.7
Soybean straw	89.9	2.3	40.1	1.0
Clover straw	84.0	4.5	31.9	1.1
PASTURE, OR FORAGE AND SOILING CROPS				
Legumes				
Alfalfa	28.2	3.6	12.1	0.4
Clover, alsike	25.2	2.6	12.5	0.6
Clover, bur	20.7	3.4	8.1	1.1
Clover, crimson	19.1	2.4	9.1	0.5
Clover, mammoth	20.0	2.0	9.9	0.3
Clover, red	29.2	2.9	14.8	0.7
Clover, sweet	20.0	2.5	9.1	0.4
Clover, white	18.5	2.9	9.7	0.5
Cowpeas	15.0	2.1	7.2	0.2
Horsebean	14.9	2.2	6.7	0.3
Lupines	16.9	2.4	8.3	0.2
Peas, Canada field	15.0	2.6	6.5	0.2
Lespedeza	36.6	4.5	17.2	0.6
Sanfoin	25.0	3.2	11.5	0.6

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
PASTURE, OR FORAGE AND SOILING CROPS (Continued)				
Legumes	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Serradella	20.5	1.8	9.6	0.5
Soybeans	24.9	3.1	11.0	0.5
Velvet beans	17.9	2.7	7.2	0.4
Vetch	18.0	3.5	7.7	0.3
Grasses				
Bermuda grass	33.2	1.9	14.9	0.5
Bluegrass, Kentucky	34.9	2.9	19.7	0.8
Bluegrass, Canada	33.2	1.3	17.2	0.4
Brome grass	34.5	3.0	15.8	0.2
Johnson grass	26.0	1.4	15.0	0.2
Millet	28.9	2.0	15.9	0.4
Orchard grass	30.0	1.7	13.7	0.5
Red top	34.7	2.0	21.3	0.6
Timothy	38.4	1.6	19.0	0.6
Barley	25.0	2.3	12.5	0.4
Oats	25.0	2.6	11.0	0.6
Rye	23.4	2.1	14.1	0.4
Dent corn	20.0	0.9	12.2	0.3
Flint corn	20.2	1.0	11.9	0.5
Sweet corn, roasting ears	20.9	1.2	12.5	0.4
Sweet corn, ears removed	20.0	0.7	11.6	0.4
Kafir	27.0	1.0	14.8	0.4
Milo	16.8	0.7	8.5	0.4
Sweet Sorghum	20.0	0.5	11.6	0.3
Durra	14.1	0.7	7.0	0.3
Broom corn	22.9	0.9	12.1	0.3
Sugar cane	15.8	0.5	8.7	0.3

TABLE 29. PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HORSES, CATTLE, AND SHEEP. (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
SILAGE				
	Per cent	*Per cent*	*Per cent*	*Per cent*
Corn, well matured	26.3	1.1	14.9	0.7
Corn, immature	20.0	0.9	11.2	0.5
Corn, frosted	25.5	1.2	14.3	0.7
Corn, ears removed	19.6	0.7	11.1	0.6
Durra	20.3	0.6	9.9	0.3
Kafir	30.8	0.9	15.2	0.5
Sorghum	23.9	0.9	12.9	0.2
Alfalfa	24.6	1.2	7.8	0.6
Apple pomace	20.3	0.5	13.0	0.6
Clover	28.0	1.3	9.4	0.5
Corn and soybean	24.0	1.7	13.0	0.7
Cowpea	22.0	1.8	10.2	0.6
Soybean	25.8	2.7	9.6	1.3
ROOTS				
Beet, common	11.5	1.4	8.9	0.5
Beet, sugar	13.6	1.1	9.9	0.1
Carrot	11.4	1.0	8.7	0.4
Mangel	8.8	0.7	5.3	0.1
Potato	21.1	1.3	15.6	—
Rutabaga	11.4	1.0	8.1	0.2
Turnip	9.4	0.9	6.0	0.1
MISCELLANEOUS ROUGHAGES				
Apple pomace	23.3	0.3	14.4	0.6
Cabbage	9.5	2.0	5.4	0.2
Kale	10.3	1.8	4.1	0.3
Pumpkin	9.1	1.0	5.6	0.4
Rape	15.5	2.0	9.6	0.2

TABLE 30. — PERCENTAGE OF TOTAL DRY SUBSTANCE AND DIGESTIBLE NUTRIENTS IN FEEDINGSTUFFS FOR HOGS [1]

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT
	Per cent	*Per cent*	*Per cent*	*Per cent*
Shelled corn	89.4	7.7	65.8	3.2
Ground corn	88.2	7.4	66.7	2.6
Corn and cob meal	89.0	6.8	59.4	3.0
Wheat	89.5	9.5	60.8	1.5
Barley	88.0	8.8	60.0	0.8
Rye	88.4	8.9	68.3	0.7
Sorghum seed	87.2	5.5	58.1	2.6
Millet seed	88.0	7.5	60.4	2.2
Rice	87.6	6.4	79.2	2.8
Wheat bran	90.0	12.1	39.1	3.2
Wheat shorts	90.0	14.8	50.2	4.2
Wheat middlings	90.0	15.0	49.4	4.1
Red dog flour	90.3	17.2	48.8	1.9
Pea meal	89.5	18.2	59.4	0.5
Linseed meal	91.5	29.2	31.2	5.0
Soybean meal	91.3	30.5	28.9	15.1
Skim milk	9.5	3.6	5.1	0.1
Buttermilk	9.6	3.6	5.0	0.2
Dried blood	91.5	60.8	—	2.0
Tankage	93.0	43.3	—	10.0
Pork cracklings	94.7	50.7	—	36.8
Potato	21.1	1.8	17.3	—

[1] Owing to the fact that hogs do not digest their feeds with the same degree of thoroughness as the other farm animals, this table has been calculated and is recommended for use in calculating rations for hogs. The table is not extensive due to the few digestion experiments which have been made with hogs.

TABLE 31. DRY SUBSTANCE, DIGESTIBLE PROTEIN, AND NET ENERGY PER 100 POUNDS OF FEED (Armsby).

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE PROTEIN[1]	NET ENERGY
Green fodder and silage	*Lbs.*	*Lbs.*	*Therms*
Alfalfa	28.2	2.50	12.45
Clover, red	29.2	2.21	16.17
Corn fodder, green	20.7	0.41	12.44
Corn silage	25.6	1.21	16.55
Hungarian grass	28.9	1.33	14.76
Rape	14.3	2.16	11.43
Rye	23.4	1.44	11.63
Timothy	38.4	1.04	19.08
Hay and dry coarse fodders			
Alfalfa hay	91.6	6.93	34.41
Clover hay, red	84.7	5.41	34.74
Corn forage, field cured	57.8	2.13	30.53
Corn stover, field cured	59.5	1.80	26.53
Cowpea hay	89.3	8.57	40.76
Hungarian hay	92.3	3.00	44.03
Oat hay	84.0	2.59	26.97
Soybean hay	88.7	7.68	38.65
Timothy hay	86.8	2.05	33.56
Straws			
Oat straw	90.8	1.09	21.21
Rye straw	92.9	0.63	20.87
Wheat straw	90.4	0.37	16.56
Roots and tubers			
Carrots	11.4	0.37	7.82
Mangels	9.1	0.14	4.62
Potatoes	21.1	0.45	18.05
Rutabagas	11.4	0.88	8.00
Turnips	9.4	0.22	5.74
Grains			
Barley	89.1	8.37	80.75
Corn	89.1	6.79	88.84
Corn-and-cob meal	84.9	4.53	72.05

[1] True protein, not crude protein.

TABLE 31. DRY SUBSTANCE, DIGESTIBLE PROTEIN, AND NET ENERGY PER 100 POUNDS OF FEED (Armsby). (Continued)

FEEDINGSTUFF	TOTAL DRY SUBSTANCE	DIGESTIBLE PROTEIN[1]	NET ENERGY
Grains (Continued)	*Lbs.*	*Lbs.*	*Therms*
Oats	89.0	8.36	66.27
Pea meal	89.5	16.77	71.75
Rye	88.4	8.12	81.72
Wheat	89.5	8.90	82.63
By-products			
Brewers' grains, dried	92.0	19.04	60.01
Brewers' grains, wet	24.3	3.81	14.82
Buckwheat middlings	88.2	22.34	75.92
Cottonseed meal	91.8	35.15	84.20
Distillers' grains, dried:			
Principally corn	93.0	21.93	79.23
Principally rye	93.2	10.38	60.93
Gluten feed, dry	91.9	19.95	79.32
Gluten meal, Buffalo	91.8	21.56	88.80
Gluten meal, Chicago	90.5	33.09	78.49
Linseed meal, O. P.	90.8	27.54	78.92
Linseed meal, N. P.	90.1	29.26	74.67
Malt sprouts	89.8	12.36	46.33
Rye bran	88.2	11.35	56.65
Sugar beet pulp, fresh	10.1	0.63	7.77
Sugar beet pulp, dried	93.6	6.80	60.10
Wheat bran	88.1	10.21	48.23
Wheat middlings	84.0	12.79	77.65

[1] True protein, not crude protein.

TABLE 32. — WOLFF-LEHMANN FEEDING STANDARDS

(Showing amounts of nutrients per day per 1000 pounds live weight)

ANIMAL	TOTAL DRY SUB-STANCE	DIGEST-IBLE CRUDE PROTEIN	DIGEST-IBLE CARBOHY-DRATES	DIGEST-IBLE FAT	NUTRI-TIVE RATIO
Oxen	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	1:
At rest in stall . . .	18	0.7	8.0	0.1	11.8
Fattening cattle					
First period	30	2.5	15.0	0.5	6.5
Second period . . .	30	3.0	14.5	0.7	5.4
Third period	26	2.7	15.0	0.7	6.2
Milch cows					
When yielding daily .					
11.0 pounds of milk .	25	1.6	10.0	0.3	6.7
16.6 pounds of milk .	27	2.0	11.0	0.4	6.0
22.0 pounds of milk .	29	2.5	13.0	0.5	5.7
27.5 pounds of milk .	32	3.3	13.0	0.8	4.5
Sheep					
Coarse wool	20	1.2	10.5	0.2	9.1
Fine wool	23	1.5	12.0	0.3	8.5
Breeding ewes					
With lambs	25	2.9	15.0	0.5	5.6
Fattening sheep					
First period	30	3.0	15.0	0.5	5.4
Second period . . .	28	3.5	14.5	0.6	4.5
Horses					
Light work	20	1.5	9.5	0.4	7.0
Medium work . . .	24	2.0	11.0	0.6	6.2
Heavy work	26	2.5	13.3	0.8	6.0
Brood sows	22	2.5	15.5	0.4	6.6
Fattening swine					
First period	36	4.5	25.0	0.7	5.0
Second period . . .	32	4.0	24.0	0.5	6.3
Third period	25	2.7	18.0	0.4	7.0
Growing cattle (dairy breeds)					
2- 3 mos. 150 lb. .	23	4.0	13.0	2.0	4.5
3- 6 mos. 300 lb. .	24	3.0	12.8	1.0	5.1
6- 12 mos. 500 lb. .	27	2.0	12.5	0.5	6.8
12-18 mos. 700 lb. .	26	1.8	12.5	0.4	7.5
18-24 mos. 900 lb. .	26	1.5	12.0	0.3	8.5

TABLE 32. WOLFF-LEHMANN FEEDING STANDARDS

(Showing amounts of nutrients per day per 1000 pounds live weight). (Continued)

ANIMAL	TOTAL DRY SUBSTANCE	DIGESTIBLE CRUDE PROTEIN	DIGESTIBLE CARBOHYDRATES	DIGESTIBLE FAT	NUTRITIVE RATIO
Growing cattle (beef breeds)	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	1:
2– 3 mos. 160 lb.	23	4.2	13.0	2.0	4.2
3– 6 mos. 330 lb.	24	3.5	12.8	1.5	4.7
6–12 mos. 550 lb.	25	2.5	13.2	0.7	6.0
12–18 mos. 750 lb.	24	2.0	12.5	0.5	6.8
18–24 mos. 950 lb.	24	1.8	12.0	0.4	7.2
Growing sheep (wool breeds)					
4– 6 mos. 60 lb.	25	3.4	15.4	0.7	5.0
6– 8 mos. 75 lb.	25	2.8	13.8	0.6	5.4
8– 11 mos. 80 lb.	23	2.1	11.5	0.5	6.0
11–15 mos. 90 lb.	22	1.8	11.2	0.4	7.0
15–20 mos. 100 lb.	22	1.5	10.8	0.3	7.7
Growing sheep (mutton breeds)					
4– 6 mos. 60 lb.	26	4.4	15.5	0.9	4.0
6– 8 mos. 80 lb.	26	3.5	15.0	0.7	4.8
8– 11 mos. 100 lb.	24	3.0	14.3	0.5	5.2
11–15 mos. 120 lb.	23	2.2	12.6	0.5	6.3
15–20 mos. 150 lb.	22	2.0	12.0	0.4	6.5
Growing swine (breeding stock)					
2– 3 mos. 50 lb.	44	7.6	28.0	1.0	4.0
3– 5 mos. 100 lb.	35	4.8	22.5	0.7	5.0
5– 6 mos. 120 lb.	32	3.7	21.3	0.4	6.0
6– 8 mos. 200 lb.	28	2.8	18.7	0.3	7.0
8–12 mos. 250 lb.	25	2.1	15.3	0.2	7.5
Growing, fattening swine					
2– 3 mos. 50 lb.	44	7.6	28.0	1.0	4.0
3– 5 mos. 100 lb.	35	5.0	23.1	0.8	5.0
5– 6 mos. 150 lb.	33	4.3	22.3	0.6	5.5
6– 8 mos. 200 lb.	30	3.6	20.5	0.4	6.0
9–12 mos. 300 lb.	26	3.0	18.3	0.3	6.4

TABLE 33. HENRY–MORRISON FEEDING STANDARDS

	DIGESTIBLE CRUDE PROTEIN	TOTAL DIGESTIBLE NUTRIENTS
Dairy Cows	*Lb.*	*Lb.*
For maintenance of 1000-lb. cow . .	0.700	7.925
To allowance for maintenance add:		
For each lb. of 2.5 per cent milk . .	0.045–0.053	0.256
For each lb. of 3.0 per cent milk . .	0.047–0.057	0.286
For each lb. of 3.5 per cent milk . .	0.049–0.061	0.316
For each lb. of 4.0 per cent milk . .	0.054–0.065	0.346
For each lb. of 4.5 per cent milk . .	0.057–0.069	0.376
For each lb. of 5.0 per cent milk . .	0.060–0.073	0.402
For each lb. of 5.5 per cent milk . .	0.064–0.077	0.428
For each lb. of 6.0 per cent milk . .	0.067–0.081	0.454
For each lb. of 6.5 per cent milk . .	0.072–0.085	0.482
For each lb. of 7.0 per cent milk . .	0.074–0.089	0.505

LIVE WEIGHT	PER 1000 LB. LIVE WEIGHT			NUTRITIVE RATIO
	Dry Substance	Digestible Crude Protein	Total Digestible Nutrients	
Growing, fattening steers	*Lb.*	*Lb.*	*Lb.*	*1:*
100 lb.	14.1	3.2	16.6	4.2
150 lb.	20.7	3.3	17.2	4.2
200 lb.	24.0	3.4	17.4	4.1
250 lb.	25.6	3.0	17.7	4.9
300 lb.	26.7	2.7	17.9	5.6
350 lb.	25.3	2.4	16.8	6.0
400 lb.	24.3	2.2	15.8	6.2
450 lb.	24.1	2.1	16.1	6.7
500 lb.	23.9	2.1	15.8	6.5
550 lb.	23.6	2.0	15.6	6.6
600 lb.	23.2	2.0	15.4	6.7
700 lb.	22.6	2.0	14.8	6.4
800 lb.	21.4	2.0	14.3	6.3
900 lb.	20.2	2.0	13.6	5.8
1000 lb.	19.7	1.8	13.5	6.5
1100 lb.	18.1	1.6	12.6	6.9
1200 lb.	17.3	1.5	12.3	7.2

TABLE 33. HENRY-MORRISON FEEDING STANDARDS. (Continued)

Animal	Per Day per 1000 Lbs. Live Weight			
	Dry Substance	Digestible Crude Protein	Total Digestible Nutrients	Nutritive Ratio
	Lb.	*Lb.*	*Lb.*	1:
Fattening 2-Yr.-Old Steers on Full Feed				
First 50–60 days .	22.0–25.0	2.0–2.3	18.0–20.0	7.0–7.8
Second 50–60 days	21.0–24.0	1.9–2.3	17.0–19.5	7.0–7.8
Third 50–60 days	18.0–22.0	1.8–2.1	16.0–18.5	7.0–7.8
Ox at Rest in Stall . .	13.0–21.0	0.6–0.8	8.4–10.4	10.0–16.0
Wintering Beef Cows in Calf	14.0–25.0	0.7–0.9	9.0–12.0	10.0–15.0
Horses				
Idle	13.0–18.0	0.8–1.0	7.0– 9.0	8.0–9.0
At light work . .	15.0–22.0	1.1–1.4	10.0–13.1	8.0–8.5
At medium work .	16.0–24.0	1.4–1.7	12.8–15.6	7.8–8.3
At heavy work .	18.0–26.0	2.0–2.2	15.9–19.5	7.0–8.0
Brood Mares Suckling Foals, but not at Work	15.0–22.0	1.2–1.5	9.0–12.0	6.5–7.5
Growing colts, Over Six Months	18.0–22.0	1.6–1.8	11.0–13.0	6.0–7.0
Fattening Lambs				
Weight 50–70 lb.	27.0–30.0	3.1–3.3	19.0–22.0	5.0–6.0
Weight 70–90 lb.	28.0–31.0	2.5–2.8	20.0–23.0	6.7–7.2
Weight 90–110 lb.	27.0–31.0	2.3–2.5	19.0–23.0	7.0–8.0
Sheep, Maintaining Mature				
Coarse wool . .	18.0–23.0	1.1–1.3	11.0–13.0	8.0–9.1
Fine wool . . .	20.0–26.0	1.4–1.6	12.0–14.0	7.5–8.5
Breeding Ewes with Lambs	23.0–27.0	2.6–2.9	18.0–20.0	5.6–6.5
Fattening Pigs				
Weight 30– 50 lb.	46.2–51.0	7.8–8.5	41.0–45.4	4.0–4.5
Weight 50–100 lb.	37.0–40.8	5.5–6.0	32.9–36.4	5.0–5.6
Weight 100–150 lb.	32.4–35.8	4.4–4.9	28.8–31.9	5.5–6.2
Weight 150–200 lb.	29.0–32.0	3.5–3.9	25.8–28.5	6.2–7.0
Weight 200–250 lb.	25.5–28.1	3.0–3.4	22.7–25.0	6.5–7.3
Weight 250–300 lb.	22.4–24.8	2.6–2.9	20.0–22.0	6.7–7.5
Brood Sows, with Pigs	20.0–24.0	2.4–2.7	18.0–21.0	6.0–7.0

Table 34. Armsby Feeding Standards

For Maintenance

Cattle			Horses	
Live weight	Digestible protein	Net energy	Digestible protein	Net energy
Lb.	*Lb.*	*Therms*	*Lb.*	*Therms*
150	0.15	1.7	0.3	2.0
250	0.20	2.4	0.4	2.8
500	0.30	3.8	0.6	4.4
750	0.40	5.0	0.8	5.8
1000	0.50	6.0	1.0	7.0
1250	0.60	7.0	1.2	8.1
1500	0.65	7.9	1.3	9.2

Sheep

Live weight	Digestible protein	Net energy
Lb.	*Lb.*	*Therms*
20	0.02	0.30
40	0.05	0.54
60	0.07	0.71
80	0.09	0.87
100	0.10	1.00
120	0.11	1.13
140	0.13	1.25

For Growth

Cattle

Age	Live weight	Digestible protein	Net energy
Months	*Lb.*	*Lb.*	*Therms*
3	275	1.10	5.0
6	425	1.30	6.0
12	650	1.65	7.0
18	850	1.70	7.5
24	1000	1.75	8.0
30	1100	1.65	8.0

TABLE 34. ARMSBY FEEDING STANDARDS. (Continued)

FOR GROWTH

SHEEP

Age	Live Weight	Digestible Protein	Net Energy
Months	*Lb.*	*Lb.*	*Therms*
6	70	0.30	1.3
9	90	0.25	1.4
12	110	0.23	1.4
15	130	0.23	1.5
18	145	0.22	1.6

FOR FATTENING[1]

CATTLE

Live weight	Digestible protein	Net energy
Lb.	*Lb.*	*Therms*
250	1.1	2.4 + (3.5 × daily gain.)
425	1.3	3.4 + (3.5 × daily gain.)
500	1.5	3.8 + (3.5 × daily gain.)
650	1.7	4.5 + (3.5 × daily gain.)
750	1.7	5.0 + (3.5 × daily gain.)
850	1.7	5.4 + (3.5 × daily gain.)
1000	1.8	6.0 + (3.5 × daily gain.)
1100	1.7	6.4 + (3.5 × daily gain.)
1250	1.6	7.0 + (3.5 × daily gain.)
1500	1.5	7.9 + (3.5 × daily gain.)

SHEEP

Live weight	Digestible protein	Net energy
40	—	0.54 + (3.5 × daily gain.)
60	—	0.70 + (3.5 × daily gain.)
70	0.30	0.79 + (3.5 × daily gain.)
80	0.28	0.87 + (3.5 × daily gain.)
90	0.25	0.94 + (3.5 × daily gain.)
100	0.24	1.00 + (3.5 × daily gain.)
110	0.23	1.06 + (3.5 × daily gain.)
120	0.23	1.13 + (3.5 × daily gain.)
130	0.23	1.19 + (3.5 × daily gain.)
140	0.22	1.25 + (3.5 × daily gain.)
145	0.22	1.28 + (3.5 × daily gain.)

[1] Modified from Armsby's original table for the sake of simplicity.

TABLE 35. — THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS [1]

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT [2]
Succulent Roughage		*Lb.*	*Lb.*	*Lb.*
Fodder corn	1	.207	.010	.138
	5	1.035	.050	.690
	15	3.105	.150	2.070
	20	4.140	.200	2.760
	25	5.175	.250	3.450
	30	6.210	.300	4.140
	35	7.245	.350	4.830
	40	8.280	.400	5.520
Red clover	1	.292	.029	.181
	5	1.460	.145	.905
	15	4.380	.435	2.715
	20	5.840	.580	3.620
	25	7.300	.725	4.525
	30	8.760	.870	5.430
	35	10.220	1.015	6.335
	40	11.680	1.160	7.240
Alfalfa	1	.282	.036	.166
	5	1.410	.180	.830
	10	2.820	.360	1.660
	15	4.230	.540	2.490
	20	5.640	.720	3.320
	25	7.050	.900	4.150
	30	8.460	1.080	4.980
	35	9.870	1.260	5.810
	40	11.280	1.440	6.640
Green sorghum . . .	1	.206	.006	.129
	5	1.030	.030	.645
	10	2.060	.060	1.290
	15	3.090	.090	1.935
	20	4.120	.120	2.580

[1] Taken from Cornell Agr. Exp. Sta. Bul. 321.

[2] Digestible protein + digestible carbohydrates + 2¼ × digestible fat.

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Succulent Roughage. (Continued)		Lb.	Lb.	Lb.
Green sorghum	25	5.150	.150	3.225
	30	6.180	.180	3.870
	35	7.210	.210	4.515
	40	8.240	.240	5.160
Mangel beets	1	.091	.010	.070
	5	.455	.050	.350
	10	.910	.100	.700
	15	1.365	.150	1.050
	20	1.820	.200	1.400
	25	2.275	.250	1.750
	30	2.730	.300	2.100
Sugar beets	1	.135	.013	.113
	5	.675	.065	.565
	10	1.350	.130	1.130
	15	2.025	.195	1.695
	20	2.700	.260	2.260
	25	3.375	.325	2.825
	30	4.050	.390	3.390
Carrots	1	.114	.008	.092
	5	.570	.040	.460
	10	1.140	.080	.920
	15	1.710	.120	1.380
	20	2.280	.160	1.840
	25	2.850	.200	2.300
	30	3.420	.240	2.760
Rutabagas	1	.114	.010	.096
	5	.570	.050	.480
	10	1.140	.100	.960
	15	1.710	.150	1.440
	20	2.280	.200	1.920
	25	2.850	.250	2.400
	30	3.420	.300	2.880

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Succulent Roughage. (Continued)		*Lb.*	*Lb.*	*Lb.*
Corn silage	1	.264	.014	.172
	5	1.320	.070	.860
	10	2.640	.140	1.720
	15	3.960	.210	2.580
	20	5.280	.280	3.440
	25	6.600	.350	4.300
	30	7.920	.420	5.160
	35	9.240	.490	6.020
	40	10.560	.560	6.880
	45	11.880	.630	7.740
	50	13.200	.700	8.600
Dried Roughage				
Timothy hay	1	.868	.028	.481
	4	3.472	.112	1.924
	6	5.208	.168	2.886
	8	6.944	.224	3.848
	10	8.680	.280	4.810
	12	10.416	.336	5.772
	14	12.152	.392	6.734
	16	13.888	.448	7.696
	18	15.624	.504	8.658
	20	17.360	.560	9.620
Red clover hay . . .	1	.847	.071	.490
	4	3.388	.284	1.960
	6	5.082	.426	2.940
	8	6.776	.568	3.920
	10	8.470	.710	4.900
	12	10.164	.852	5.880
	14	11.858	.994	6.860
	16	13.552	1.136	7.840
	18	15.246	1.278	8.820
	20	16.940	1.420	9.800

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Dried Roughage. (Continued)		*Lb.*	*Lb.*	*Lb.*
Alfalfa hay	1	.918	.105	.530
	4	3.672	.420	2.120
	6	5.508	.630	3.180
	8	7.344	.840	4.240
	10	9.180	1.050	5.300
	12	11.016	1.260	6.360
	14	12.852	1.470	7.420
	16	14.688	1.680	8.480
	18	16.524	1.890	9.540
	20	18.360	2.100	10.600
Mixed grasses and clover	1	.871	.058	.505
	4	3.484	.232	2.020
	6	5.226	.348	3.030
	8	6.968	.464	4.040
	10	8.710	.580	5.050
	12	10.452	.696	6.060
	14	12.194	.812	7.070
	16	13.936	.928	8.080
	18	15.678	1.044	9.090
	20	17.420	1.160	10.100
Hungarian hay . . .	1	.923	.045	.590
	4	3.692	.180	2.360
	6	5.538	.270	3.540
	8	7.384	.360	4.720
	10	9.230	.450	5.900
	12	11.076	.540	7.080
	14	12.922	.630	8.260
	16	14.768	.720	9.440
Millet hay	1	.840	.020	.459
	4	3.360	.080	1.836
	6	5.040	.120	2.754
	8	6.720	.160	3.672

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Dried Roughage. (Continued)		*Lb.*	*Lb.*	*Lb.*
Millet hay	10	8.400	.200	4.590
	12	10.080	.240	5.508
	14	11.760	.280	6.426
	16	13.440	.320	7.344
Corn fodder	1	.578	.025	.398
	5	2.890	.125	1.990
	8	4.624	.200	3.184
	12	6.936	.300	4.776
	15	8.670	.375	5.970
	18	10.404	.450	7.164
	20	11.560	.500	7.960
Corn stover	1	.595	.014	.342
	5	2.975	.070	1.710
	8	4.760	.112	2.736
	12	7.140	.168	4.104
	15	8.925	.210	5.130
	18	10.710	.252	6.156
	20	11.900	.280	6.840
Dried sorghum . . .	1	.889	.027	.457
	4	3.556	.108	1.828
	6	5.334	.162	2.742
	8	7.112	.216	3.656
	10	8.890	.270	4.570
	12	10.668	.324	5.484
	14	12.446	.378	6.398
	16	14.224	.432	7.312
	18	16.002	.486	8.226
	20	17.780	.540	9.140
Oat straw	1	.908	.013	.426
	3	2.724	.039	1.278
	5	4.540	.065	2.130
	8	7.264	.104	3.408

Table 35. The Amounts of Digestible Nutrients in Different Amounts of Feeds. (Continued)

Kind of Feed	Lbs. of Feed	Dry Substance	Digestible Protein	Total Nutriment
Dried Roughage. (Continued)		Lb.	Lb.	Lb.
Oat straw	12	10.896	.156	5.112
	15	13.620	.195	6.390
	18	16.344	.234	7.668
Wheat straw	1	.904	.008	.369
	3	2.712	.024	1.107
	5	4.520	.040	1.845
	8	7.232	.064	2.952
	12	10.848	.096	4.428
	15	13.560	.120	5.535
	18	16.272	.144	6.642
Concentrates				
Corn (dent)	1	.894	.078	.843
	2	1.788	.156	1.686
	3	2.682	.234	2.529
	4	3.576	.312	3.372
	5	4.470	.390	4.215
	6	5.364	.468	5.058
	7	6.258	.546	5.901
	8	7.152	.624	6.744
	9	8.046	.702	7.587
Corn and cob meal	1	.849	.044	.709
	2	1.698	.088	1.418
	3	2.547	.132	2.127
	4	3.396	.176	2.836
	5	4.245	.220	3.545
	6	5.094	.264	4.254
	7	5.943	.308	4.963
	8	6.792	.352	5.672
	9	7.641	.396	6.381
Hominy chop	1	.904	.068	.840
	2	1.808	.136	1.680
	3	2.712	.204	2.520
	4	3.616	.272	3.360

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Concentrates. (Continued)				
Hominy chop		*Lb.*	*Lb.*	*Lb.*
	5	4.520	.340	4.200
	6	5.424	.408	5.040
	7	6.328	.476	5.880
	8	7.232	.544	6.720
	9	8.136	.612	7.560
Gluten feed	1	.908	.213	.806
	2	1.816	.426	1.612
	3	2.724	.639	2.418
	4	3.632	.852	3.224
	5	4.540	1.065	4.030
	6	5.448	1.278	4.836
	7	6.356	1.491	5.642
	8	7.264	1.704	6.448
	9	8.172	1.917	7.254
Distillers' dried grains	1	.924	.228	.886
	2	1.848	.456	1.772
	3	2.772	.684	2.658
	4	3.696	.912	3.544
	5	4.620	1.140	4.430
	6	5.544	1.368	5.316
	7	6.468	1.596	6.202
	8	7.392	1.824	7.088
	9	8.316	2.052	7.974
Oats	1	.896	.088	.675
	2	1.792	.176	1.350
	3	2.688	.264	2.025
	4	3.584	.352	2.700
	5	4.480	.440	3.375
	6	5.376	.528	4.050
	7	6.272	.616	4.725
	8	7.168	.704	5.400
	9	8.064	.792	6.075

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (*Continued*)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Concentrates. (Continued)		*Lb.*	*Lb.*	*Lb.*
Wheat	1	.895	.100	.798
	2	1.790	.200	1.596
	3	2.685	.300	2.394
	4	3.580	.400	3.192
	5	4.475	.500	3.990
	6	5.370	.600	4.788
	7	6.265	.700	5.586
	8	7.160	.800	6.384
	9	8.055	.900	7.182
Wheat bran	1	.881	.119	.595
	2	1.762	.238	1.190
	3	2.643	.357	1.785
	4	3.524	.476	2.380
	5	4.405	.595	2.975
	6	5.286	.714	3.570
	7	6.167	.833	4.165
	8	7.048	.952	4.760
	9	7.929	1.071	5.355
Wheat middlings . . .	1	.900	.169	.797
	2	1.800	.338	1.594
	3	2.700	.507	2.391
	4	3.600	.676	3.188
	5	4.500	.845	3.985
	6	5.400	1.014	4.782
	7	6.300	1.183	5.579
	8	7.200	1.352	6.376
	9	8.100	1.521	7.173
Red dog flour	1	.915	.162	.809
	2	1.830	.324	1.618
	3	2.745	.486	2.427
	4	3.660	.648	3.236
	5	4.575	.810	4.045
	6	5.490	.972	4.854
	7	6.405	1.134	5.663
	8	7.320	1.296	6.472
	9	8.235	1.458	7.281

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Concentrates. (Continued)		*Lb.*	*Lb.*	*Lb.*
Barley	1	.892	.084	.773
	2	1.784	.168	1.546
	3	2.676	.252	2.319
	4	3.568	.336	3.092
	5	4.460	.420	3.865
	6	5.352	.504	4.638
	8	6.244	.588	5.411
	7	7.136	.672	6.184
	9	8.028	.756	6.957
Malt sprouts	1	.905	.203	.695
	2	1.810	.406	1.390
	3	2.715	.609	2.085
	4	3.620	.812	2.780
	5	4.525	1.015	3.475
	6	5.430	1.218	4.170
	7	6.335	1.421	4.865
	8	7.240	1.624	5.560
	9	8.145	1.827	6.255
Brewers' wet grains	1	.243	.039	.164
	5	1.215	.195	.820
	10	2.430	.390	1.640
	15	3.645	.585	2.460
	20	4.860	.780	3.280
	25	6.075	.975	4.100
	30	7.290	1.170	4.920
	35	8.505	1.365	5.740
Brewers' dried grains	1	.913	.200	.657
	2	1.826	.400	1.314
	3	2.739	.600	1.971
	4	3.652	.800	2.628
	5	4.565	1.000	3.285
	6	5.478	1.200	3.942
	7	6.391	1.400	4.599
	8	7.304	1.600	5.256
	9	8.217	1.800	5.913

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Concentrates. (Continued)		*Lb.*	*Lb.*	*Lb.*
Rye	1	.913	.095	.815
	2	1.826	.190	1.630
	3	2.739	.285	2.445
	4	3.652	.380	3.260
	5	4.565	.475	4.075
	6	5.478	.570	4.890
	7	6.391	.665	5.705
	8	7.304	.760	6.520
	9	8.217	.855	7.335
Canada field peas . .	1	.850	.197	.699
	2	1.700	.394	1.398
	3	2.550	.591	2.097
	4	3.400	.788	2.796
	5	4.250	.985	3.495
	6	5.100	1.182	4.194
	7	5.950	1.379	4.893
	8	6.800	1.576	5.592
	9	7.650	1.773	6.291
Cottonseed meal . . .	1	.930	.376	.806
	2	1.860	.752	1.612
	3	2.790	1.128	2.418
	4	3.720	1.504	3.224
	5	4.650	1.880	4.030
	6	5.580	2.256	4.836
	7	6.510	2.632	5.642
	8	7.440	3.008	6.448
	9	8.370	3.384	7.254
Linseed oil meal . . .	1	.902	.302	.777
	2	1.804	.604	1.554
	3	2.706	.906	2.331
	4	3.608	1.208	3.108
	5	4.510	1.510	3.885
	6	5.412	1.812	4.662

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Concentrates. (Continued)		*Lb.*	*Lb.*	*Lb.*
Linseed oil meal . . .	7	6.314	2.114	5.439
	8	7.216	2.416	6.216
	9	8.118	2.718	6.993
Buckwheat middlings .	1	.872	.227	.739
	2	1.744	.454	1.478
	3	2.616	.681	2.217
	4	3.488	.908	2.956
	5	4.360	1.135	3.695
	6	5.232	1.362	4.434
	7	6.104	1.589	5.173
	8	6.976	1.816	5.912
	9	7.848	2.043	6.651
Culled beans	1	.859	.226	.759
	2	1.718	.452	1.518
	3	2.577	.678	2.277
	4	3.436	.904	3.036
	5	4.295	1.130	3.795
	6	5.154	1.356	4.554
	7	6.013	1.582	5.313
	8	6.872	1.808	6.072
	9	7.731	2.034	6.831
Sugar molasses . . .	1	.741	.014	.606
	2	1.482	.028	1.212
	3	2.223	.042	1.818
	4	2.964	.056	2.424
	5	3.705	.070	3.030
	6	4.446	.084	3.636
	7	5.187	.098	4.242
	8	5.928	.112	4.848
	9	6.669	.126	5.454
Skimmed milk . . .	1	.094	.029	.089
	4	.376	.116	.356
	6	.564	.174	.534

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Concentrates. (Continued)		*Lb.*	*Lb.*	*Lb.*
Skimmed milk	8	.752	.232	.712
	10	.940	.290	.890
	12	1.128	.348	1.068
	14	1.316	.406	1.246
	16	1.504	.464	1.424
	18	1.692	.522	1.602
	20	1.880	.580	1.780
	22	2.068	.638	1.958
	24	2.256	.696	2.136
Buttermilk	1	.098	.038	.100
	3	.294	.114	.300
	5	.490	.190	.500
	8	.784	.304	.800
	10	.980	.380	1.000
	12	1.176	.456	1.200
	15	1.470	.570	1.500
	18	1.764	.684	1.800
	20	1.960	.760	2.000
	25	2.450	.950	2.500
	30	2.940	1.140	3.000
Wet beet pulp	1	.102	.005	.082
	5	.510	.025	.410
	10	1.020	.050	.820
	15	1.530	.075	1.230
	20	2.040	.100	1.640
	25	2.550	.125	2.050
	30	3.060	.150	2.460
	35	3.570	.175	2.870
	40	4.080	.200	3.280
Dried beet pulp	1	.916	.041	.690
	2	1.832	.082	1.380
	3	2.748	.123	2.070
	4	3.664	.164	2.760

TABLE 35. THE AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT AMOUNTS OF FEEDS. (Continued)

KIND OF FEED	LBS. OF FEED	DRY SUBSTANCE	DIGESTIBLE PROTEIN	TOTAL NUTRIMENT
Concentrates. (Continued)		*Lb.*	*Lb.*	*Lb.*
Dried beet pulp . . .	5	4.580	.205	3.450
	6	5.496	.246	4.140
	7	6.412	.287	4.830
	8	7.328	.328	5.520
	9	8.244	.369	6.210

INDEX

Numbers refer to pages.

Abomasum, 35–6
  digestion in, 42–4
Absorption of nutrients, 47–55
  work of, 99–100
Acid in gastric juice, 41–2
Adulteration of feeds, 223–6
Age of animal, influence on digestibility, 67
  efficiency of gains, 313–5
  fat content of body, 28–9
  protein content of body, 29–30
  value of manure, 3, 24
  water content of body, 27
Alfalfa hay, 237–41
  composition, 239
  digestibility of protein of, 64
  compared with clover, 237, 239
  curing, 239
  feeding value, 239
  for breeding stock, 240
    fattening stock, 240
    growing stock, 239–40
    milk cows, 241
    work horses, 241
  ground, *see* Alfalfa meal
  net energy value, 239
Alfalfa meal, 300–1
Alfalfa pasture, 272–3
Alfalfa silage, 294
Alfalfa soilage, 267–8, 269, 272
Alfalfa straw, 264–5
Alimentary tract, 34
Alsike clover, *see* Clover, alsike
Amides, 11
Amino acids, absorption of, from intestine, 48, 51
  definition, 10
  end products of oxidation of, 81
  function of, in animal body, 81–2
Amino acids, influence on animals of rations deficient in, 11, 82–7
  in large intestine, 47, 52
    small intestine, 45, 46, 51
      absorption, 48, 51
Amount of feed, how determined in compounding rations, 112
  influence of, on digestibility of feedingstuffs, 72–3
    efficiency of grains, 307–9
Amylase, pancreatic, 44, 45, 53
  salivary, 39, 40, 41, 52–3
Amylopsin, *see* Amylase, pancreatic
Animals, *see* Farm animals
Apple pomace, 304
Armsby's energy values for feedingstuffs, Appendix Table 30
  feeding standards, 124–8, 148, 149, Appendix Table 34
  standard for dairy cows compared with other standards, 148
    Van Norman modification of, 128–9
  values for dry substance, digestible protein and energy in feeding stuffs, Appendix Table 31
Artichokes, 299–300
Ash, *see* Mineral matter
Assimilation, *see* Absorption
Available energy, *see* Metabolizable energy

Bacteria, action in digestion, 46–7, 52, 53–4
Bagasse, sorghum, for silage, 295
Balanced ration, 119
  See also Ration
Bales of hay, weights of, 115

Barley, 176–9
composition, 176
for breeding stock, 179
fattening stock, 178
growing stock, 177–8
milk cows, 179
work horses, 179
net energy value, 176
vs. corn for pork and bacon production, 176
See also Cereals, Feedingstuffs
Barley by-products, 199–202
Barley hay, 254–5
Barley pasture, 284
Barley straw, 264
Beans, field, 186
velvet, *see* Velvet bean
Beef cattle, *see* Steers
Beef production as influenced by grade of animal, 312–3
Beet, mangel, *see* Mangels
sugar, *see* Sugar beet
Beet molasses, *see* Molasses
Beet pulp, 228–9
Beet pulp silage, 295
Beet tops, 304
Beggar weed hay, 244
Beggar weed pasture, 274
Bermuda grass, 250, 253
Bermuda hay, 250, 253
Bermuda pasture, 282
Bile, 38, 44, 45–6, 54
Bloat in farm animals, 43
how prevented, 271, 302
Blood flour, 219
Blood meal or dried blood, 218–9
Bluegrass pasture, Canada, 281
Kentucky, 278–80
Body temperature of farm animals, 103–5
Body weight of farm animals, composition of increase in, 30–3
Bomb calorimeter, 93–5, 97
Bone meal, raw, 219–20
steamed, 220
Bones of farm animals, influenced by feed, 78, 79–80, 83, 84–6
mineral matter in, 27, 28, 77
water in, 27

Bran, *see* names of kinds of bran as Wheat bran
Breed or type of animal, influence of, on digestibility of feedingstuffs, 67
efficiency of gains, 312–3
value of manure, 324
value in beef production, 312–3
Breeding stock, alfalfa hay for, 240
alfalfa straw for, 264–5
barley for, 179
barley straw for, 264
Canada field peas for, 184
carrots for, 298
corn for, 164–5
corn silage for, 292–3
corn stover for, 261
cottonseed meal or cake for, 212
gluten feed for, 191
Kentucky bluegrass for, 278
linseed meal or cake for, 208–9
mangels for, 298
oats for, 172–3
oat straw for, 264
red clover hay for, 236–7
rye for, 175
rye pasture for, 283
timothy hay for, 247
wheat bran for, 196
wheat for, 169
wheat middlings for, 198
Brewers' grains, 199–201
Brome grass, 253
Brome hay, 253
Brome pasture, 282–3
Broom corn fodder, 260
Buckwheat by-products, 205
Bull and Emmett standard of protein requirements for lambs, 132–3
Butter, influence of coconut meal or cake on, 215
cottonseed meal or cake on, 212
gluten feed on, 191
linseed meal or cake on, 209
rye on, 173
soybeans on, 185
Buttermilk, 229

Cabbage, 302
Cæcum, 36

Calcium, excretion from animal body, 78
in bodies of farm animals, 28
influence on pigs of ration deficient in, 79–80
required for growth, 78–80, 131
Calcium phosphate, 79
Calorie, 93
Calorimeter, bomb, 93–5, 96, 97
respiration, 96–7
Calves
(For the value of a particular feed for calves, *see* name of feed)
ash of feed excreted in manure, 323
composition of bodies, 26
increase in body weight, 32
digestible organic matter required for 1 lb. of gain, 315
efficiency of gains, 315
fat in bodies, 26, 28
increase in body weight, composition, 32
manure of, ash and nitrogen of feed excreted in, 323
nitrogen of feed excreted in manure, 323
protein in bodies, 26, 30
rations for, 110
water in bodies, 26, 27
Canada blue grass, 281
Canada field pea, 183–4
Cane molasses, 227
Cane sugar, 13, 14
digestion of, 45, 46, 53
Cannery refuse for silage, 295
Capacity of animal, influence on efficiency of gains, 315–6
Capillaries, 48, 49, 50, 51, 52, 53, 54
Carbohydrates, 13
absorption of, 88
a source of energy, 87–8
composition and subclasses of, 14
fat formed from, 87–9
function in animal body, 87–9
glycogen formed from, 87–8
gross energy of, 95
in animal body, 30
influence on digestibility of excess of, in ration, 73–4
net energy of, *101*
Carbohydrates, should be limited for breeding stock, 131
See also Crude fiber and Nitrogen-free extract
Carbon dioxide, 43, 54
Carbonaceous concentrates, 106
Carbonic acid gas, *see* Carbon dioxide
Carrots, 298–9
Casein, 42, 45, 51, 82
Cassava, 300
Cattle, *see* Steers, Cow, Cows, dairy
Cellulose, 13, 14, 16–7
digestion of, 43, 53
Cereal by-products, 188–205
crude fiber in, 17–8
crude protein in, 12–3
fat in, 22
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5–6
Cereal grains, *see* Cereals
Cereals, 158–83
crude fiber in, 17–8
crude protein in, 12–3
fat in, 21–2
mineral matter in, 8–9
nitrogen-free extract in, 15–6
water in, 5–6
Chlorine in feedingstuffs, 8
Chufas, 300
Chyme, 44
Climate, influence of, on efficiency of rations, 319
Clover, alsike, 242, 273
bloat from, how prevented, 271
crimson, 243, 274
for soilage, 267–8
Japan, *see* Lespedeza
mammoth, 241–2, 273
red, 234, 270–2
sweet, 242–3, 273
white, 273
Clover hay, alsike, 242
crimson, 243
Japan, *see* Lespedeza hay
mammoth, 241–2
red, 234–7
composition, 234
energy value, 234
for breeding stock, 236–7

Clover hay, red, for fattening stock, 236
growing stock, 235–6
milk cows, 237
work horses, 237
time to cut, 235
sweet, 242–3
Clover pasture and soilage, 267–8
alsike, 273
crimson, 274
Japan, *see* Lespedeza pasture
mammoth, 273
red, 270–2
bloat from, how prevented, 271
composition, 270–1
net energy value, 271
sweet, 273
white, 273
Clover silage, 294
Clover straw, 264–5
Coarse forage, *see* Roughage
Cocoa shells, 230
Coconut meal or cake, 214–5
Coefficients, of digestibility, 56–66
definition, 56
how determined, 56–63
indirect method of calculating, 60–3
errors in, 62–3
not exact, 59–60
of crude fiber, 65–6
crude protein, 64
fat, 66
feeds that cannot be fed alone, how determined, 60–3
mineral matter, 63–4
nitrogen-free extract, 64–5
utilization of energy, 102–3
Colts, rations for, 109
(For the value of a particular feed for colts, *see* name of feed)
Combustion, heat of, 93–5
Commercial feeds, 223–6
influence of, on digestibility of ration, 70–1
standards for use in buying, 224–5
Common salt, *see* Salt
vetch, *see* Vetch, common
Composition of farm animals, 25–33
feedingstuffs, 1–24, Appendix Table 28
Composition of farm animals, increase in body weight of farm animals, 30–3
meat-producing animals, 26
ration as affecting its efficiency, 306–7
steers, 26, 29
Compounding of rations, 107–12
Compounds, 2–3
Concentrates, average weights of, 114
carbonaceous, 106
compared with roughages in digestibility of:
crude fiber, 65
crude protein, 64
fat, 66
nitrogen-free extract, 64–5
estimating weights of, 112–3
in rations, 112–3
proportion of, to roughages in ration as affecting efficiency of gains, 307
valuation of, as compared with roughages, 332–3
weights of, 114
Condition of animal, influence of, on composition of body, 26
digestibility, 67
fat content of body, 28
mineral content of body, 28
protein content of body, 30
water content of body, 27
Cooking, influence of, on digestibility, 69
efficiency of ration, 310
Corn, 159–66
a fattening feed, 161, 163
by-products, 188–93
composition of, 161
deficient in mineral matter and protein, 78–9, 83, 161
dent, 160
flint, 160
for breeding stock, 164–5
fattening stock, 163–4
growing stock, 162–3
milk cows, 165
work horses, 165–6
forms in which fed, 161–2
net energy value of, 161

Corn, for silage, 290
soft, 166
source of starch and glucose, 188
yellow compared with white, 160–1
Corn bran, 191–2
Corn chop, *see* Corn meal
Corn fodder, 256–7
Corn fodder silage, 289–94
Corn forage, *see* Corn fodder, Corn stover, Corn pasture
Corn gluten feed, see Gluten feed
Corn meal, *see* Corn oil or germ meal
Corn molasses, *see* Molasses
Corn oil, 20
Corn oil or germ meal, 192
Corn pasture, 284–6
Corn silage, see Silage, corn
Cornstalk disease, 284–5
Cornstarch, 13
Corn stover, 261–2
Cost of feeds considered in formulating rations, 330–3
Cotton seed, 187
Cottonseed by-products, 210–3
Cottonseed cake, *see* Cottonseed meal or cake
Cottonseed feed, 213–4
Cottonseed-hull bran, 214
Cottonseed hulls, 214
Cottonseed meal or cake, 210–13
cold pressed, 213
composition of, 210
dangerous for hogs, 211, 212
for breeding stock, 212
fattening stock, 211–2
growing stock, 211
milk cows, 212
work horses, 212–3
grades of, 211
makes hard butter, 212
net energy value of, 210
Cottonseed oil, 20
Cow, large intestine of, 37
manure excreted by, per year, 321
saliva secreted by, 40
salivary glands of, 38
small intestine of, 36
stomach of, 35–6
See also Cows, dairy
Cowpea, 184
Cowpea hay, 244–5
Cowpea pasture, 275, 277
Cowpea silage, 294
Cowpea straw, 265–6
Cows, dairy
(For the value of a particular feed for dairy cows, *see* name of feed)
Armsby feeding standards for, 124–5, 148
breed of, as affecting requirements for milk production, 147
calculating rations for, 126–8, 129, 142, 144–5, 145
climate as affecting efficiency of rations of, 319
Eckle's feeding standards for, 147–8
exercise for, 316
grinding feed for, 309–10
Haecker's feeding standards for, 140–1, 148
mineral matter of feed excreted by, 322, 323
products of, per 100 lbs. digestible organic matter, 311
rations for, calculating, 126–8, 129, 142, 144–5, 145
examples of, 110
size of, 309
requirements for milk production, 139–48
Savage feeding standards for, 142–5, 148
shelter for, 319
shredding corn stover for, 310
size of ration for, 309
temperature as affecting efficiency of rations of, 319
Van Norman feeding standards for, 128–9
Woll and Humphrey feeding standards for, 145–6, 148
Cracklings, 219
Crimson clover, *see* Clover, crimson
Crops for the silo, 287–95
Crude fiber, *see* Fiber
Crude protein, *see* Protein, crude
Cud, chewing the, 42–3

Dent corn, 160
Dextrin, 14
Dietrich's feeding standard for growing pigs, 133
market hogs, 137
Digestibility, 56–75
coefficients of, 56–66
definition, 56
how determined, 56–63
indirect method of calculating, 60–3
errors in, 62–3
not exact, 59–60
of crude fiber, 65–6
crude protein, 64
fat, 66
feeds that cannot be fed alone, how determined, 60–3
mineral matter, 63–4
nitrogen-free extract, 64–5
influence of addition of nitrogenous nutrients to ration on, 74
age of animal on, 67
amounts of feed on, 72–3
breed of animal on, 67
condition of animal on, 67
cooking of feeds on, 69
curing of feeds on, 71
excess of non-nitrogenous nutrients in ration on, 73
fermenting of feeds on, 69
frequency of feeding and watering animals on, 70
grinding feed on, 69–70
individuality of animals on, 68
palatability of ration on, 68–9
patent stock feeds on, 70–1
preparation of feeds on, 69–70
proportion of different nutrients in ration on, 73–4
salt on, 71
soaking of feeds on, 69
species of animal on, 67–8
stage of growth of plant on, 71–2
storage of feeds on, 72
sweating of feeds on, 69
work of animal on, 67–8
of crude fiber, 65–6
crude protein, 64
Digestibility, of fat, 66
feedingstuffs, 56–66, Appendix Tables 29, 30, 31, 35
mineral matter, 63–4
nitrogen-free extract, 64–5
relation of, to efficiency of ration, 307
value of manure, 323
Digestible nutrients, in feedingstuffs, 74–5, Appendix Tables 29, 30, 31, 35
yield of, per acre by grains and seeds, 159
Digestion, 40–7
energy expended in, 99–100
in large intestine, 46–7
mouth, 40–1
small intestine, 44–6
stomach, 41–4
of crude fiber, 53–4
fat, 54–5
mineral matter, 51
nitrogen-free extract, 52–3
nutrients, 40–55
protein, 51–2
organs of, 34–8
work involved in, 99–100
Digestion coefficients, 56–66
definition, 56
how determined, 56–63
indirect method of calculating, 60–3
errors in, 62–3
not exact, 59–60
of crude fiber, 65–6
crude protein, 64
fat, 66
feeds that cannot be fed alone, how determined, 60–3
feedingstuffs, 56–66
mineral matter, 63–4
nitrogen-free extract, 64–5
Digestion experiments, methods of conducting, 56–8
Digestive system of farm animals, 34–8
Distillers' grains, 192–3
Distillers' slop, 192
Dried beet pulp, 228–9
Dried blood, 218–9

Dried brewers' grains, 200–1
Dried distillers' grains, 192–3

Eckles' feeding standards for dairy cows, 147–8
Economy in feeding livestock, 331–5
Efficiency of rations, 305–19
  influence of age of animal on, 313–5
    capacity of animal on, 316
    climate on, 319
    digestibility of ration on, 307
    species of animal on, 310–2
    temperature conditions on, 319
    type of animal on, 312–3
Egyptian corn, *see* Milo maize
Elements, 1–2
Emmer, 179
Energy, 93–106
  Armsby's values for, in feedingstuffs, *Appendix Table 31*
  available, *see* Metabolizable
  bomb calorimeter for determining, 93–5, 96, 97
  carbohydrates a source of, 87, 88
  coefficient of utilization of, 102–3
  derived from the sun, 92–3
  expended in digestion and absorption of nutrients, 99–100
    heat production, 100, 103–5
    vital processes, 98–100
  fat a source of, 89
  gross, 93–5, 95–6
    how determined, 93–5
    of nutrients, 95
  in feedingstuffs, 105, Appendix Table 31
    how determined, 93–5, 96–7
    nutrients, 95, 101
  kinds of, 92
  kinetic, 92–3
  losses of, 95, 100, 103–4
  measurement of, 93
  metabolizable, 95–8
    definition, 95
    how determined, 96–7
    uses of, in animal body, 97–8
  net, 100–1
    definition, 100
    how determined, 101
Energy, net, in feedingstuffs, 105, Appendix Table 31
      nutrients, 101
    recovered in work, 103
    required for work of voluntary muscles, 101–2
  of animal body compared with steam engine, 92–3, 100, 103
    ration liberated in heat by steers, 100
  potential, 92–3
  protein a source of, 80, 81
  required for work of digestion and absorption, 99–100
    heat production, 103–5
    vital processes, 98–100
    voluntary muscles, 101–2
  respiration calorimeter for determining, 96–7, 101
  storage of, 105
  units of measurement of, 93
  utilization of, coefficients, 102–3
Energy values of feeds, Armsby's, 105, Appendix Table 31
Engine compared with animals, 92–3, 100, 103
Ensilage, *see* Silage
Ensiling, method by which green fodder is preserved by, 287
Enterokinase, 46
Enzymes, 38–40
Erypsin, 44–5, 46
Esophagus, 34, 41
Ether extract, *see* Fat
Ewes, concentrates and roughage for, 112
  (For the value of a particular feed for ewes, *see* name of feed)
Excrement, *see* Manure
Exercise for fattening stock and dairy cows, 316
Exposure, influence of, on efficiency of rations, 319

Farm animals, absorption of nutrients by, 47–9, 50–5
  age of, as affecting digestibility of rations, 67
    efficiency of rations, 313–5
    value of manure, 324

Farm animals, ash in bodies of, 26, 27–8
of feed excreted in manure of, 323
breed of, as affecting digestibility of rations, 67
capacity of, as affecting efficiency of rations, 315–6
carbohydrates in bodies of, 30
composition of bodies of, 25–33
increase in body weight of, 30–3
compounding of rations for, 107–12
condition of, as affecting digestibility of ration, 67
digestion of nutrients by, 40–7, 50–5
digestive systems of, 34–8
efficiency of gains of, 305–19
energy, use of, by, 92–3, 97–100, 101–5
fat in bodies of, 26, 28–9
feed requirements of, 119–49
feeding standards for, 119–29, 130, 131–4, 136–8, 139–49, Appendix Tables
grade of, as affecting efficiency of rations, 312–3
heat production in bodies of, 103–5
individuality of, as affecting digestibility of ration, 68
increase in body weight of, composition, 30–3
manure voided by, per year, 321
mineral matter in bodies of, 26, 27–8
of feed excreted in manure of, 323
nitrogen of feed excreted in manure of, 323
phosphorus of feed excreted in manure of, 323
protein in bodies of, 26, 29–30
rations for, compounding of, 107–12
requirements for fattening, 135–7
growth, 130–4
maintenance, 129–30
pregnancy, 134
self-feeders for, 152–6
Farm animals, species of, as affecting digestibility of rations, 66–7
efficiency of rations, 310–2
value of manure, 324–5
storage of energy by, 105
temperament of, as affecting efficiency of rations, 316
treatment of, as affecting efficiency of rations, 316–7
type of, as affecting efficiency of rations, 312–3
water in bodies of, 26–7
work of, as affecting digestibility of rations, 67–8
Farm manure, *see* Manure
Fat, 18–21
absorption of, 49, 54–5
a source of muscular energy and body fat, 88, 89
composition of, 18–9
digestibility of, 66
digestion of, 42, 45, 46, 54–5
energy values of, as compared with other nutrients, 19
function in animal body, 89
gross energy of, 95
in animal body formed from carbohydrates of feed, 87, 88–9
crude protein of feed, 81
fat of feed, 89
bodies of farm animals, 26, 28–9
feedingstuffs, 21–2
how determined, 21
increase in body weight, 30–3
soap making, 20, 45
vegetable substances, 18
net energy value of, 101
wool, 20
Fattening, composition of increase during, 31–3
factors affecting, 306–19
influence of age of animal on, 313–5
amount of ration on, 307–9
capacity of animal on, 315–6
climatic conditions on, 319
composition of ration on, 306–7
digestibility of ration on, 307
grade of animal on, 312–3

Fattening, *influence of length of fattening period on*, 317–8
preparation of ration on, 309–10
previous treatment of animal on, 316–7
species of animal on, 310–2
temperament of animal on, 316
temperature on, 319
type of animal on, 312–3
object of, 31
requirements of animals for, 315–7
Fattening period, length of, as affecting efficiency of rations, 317–8
Fattening process, what it is, 31
Fatty tissues, storage of, *see* Fattening
Feces, 47
energy lost in, 95
Feed, amounts of, how determined, 112–3
influence of, on digestibility of ration, 72–3
efficiency of ration, 307–8
influence of preparation of, on digestibility of ration, 69–70, 72–3
efficiency of ration, 309–10
See also Feedingstuffs
Feed adulteration, 223–6
Feeding standards, 119–49, 151–2
for dairy cows, comparison of, 148
Eckles, 147–8
Haecker's, 148
Hansson's, 151–2
Savage's, 142–5
Van Norman's, 128–9
Woll-Humphrey, 145–6
for farm animals, 120–1, 124, 125–6
Armsby's, 125–6, Appendix Table 34
Henry-Morrison, 124, Appendix Table 33
Wolff-Lehmann, 120–1, Appendix Table 32
for horses, Kellner, 138
Savage, 134
for lambs, Bull-Emmett, 132–3, 136
for pigs, Dietrich's, 133, 137
Feeding stuffs, 157–304
adulteration of, 223–6
coefficients of digestibility of, 56–75
commercial values of, as fertilizers, 327–9
composition of, 1–24, Appendix Tables 28, 29, 30, 31, 35
crude fiber in, 17–8
crude protein in, 12–3
digestibility of, 56–75
digestible nutrients in, 74–5, Appendix Tables 29, 30, 31, 35
dry substance in, Appendix Tables 29, 30, 31, 35
energy values of, 93–7, 100–1, 105–6, Appendix Table 31
fat in, 21–2
fertilizing values of, 320–9
gross energy of, 93–5
metabolizable energy of, 95–7
mineral matter in, 7–9
net energy of, 100–1, 105, Appendix Table 31
nitrogen-free extract in, 15–6
nutrients in, 2–3, Appendix Tables 29, 30, 31, 35
valuation of, 330–3
vitamines in, 22–4
water in, 4–6
See also Feed
Feeds, commercial, *see* Commercial feeds
Feed unit system of calculating rations, 149–52
Fermentation, influence of, on digestibility of feedingstuffs, 69
value of manure, 326–7
in large intestine, 47, 52, 53
stomach, 43, 53–4
Ferments, *see* Enzymes
Fertility, buying with feeds, 320–1
Fertilizers, essential elements of, 320
Fertilizing values of feedingstuffs, 320–9
Feterita, 258, 260
Feterita fodder, 258, 260
Feterita silage, 294–5
Feterita stover, 262

Fiber, 14, 16–7
absorption of digestion — products of, 48
digestibility of, 65–6
digestion of, 43, 47, 53
how determined in feedingstuffs, 17
in feedingstuffs, 17–8
Fibrin, 45, 51
Field bean, *see* Bean, Field
Field pea, Canada, 183–4
Finish in fattening animals, 308–9
Flax by-product, 209
Flax feed, 209
Flax oil feed, 209–10
Flax screenings, 209
Flaxseed, 187
Flaxseed by-product, 206–9
Flax straw, 264
Flint corn, 160
Flour, blood, 219
red dog, 198–9
Foals, rations for, 109
(For the value of a particular feed for foals, *see* name of feed)
Fodder, corn, 256–7
Fodders, 256–62
crude fiber in, 17–8
crude protein in, 12–3
fat in, 22
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5
Forage, coarse, *see* Roughage
Forage crops, 266–7
Frequency of feeding and watering, *influence of, on digestibility* of ration, 70
Frosted corn, 166, 290
Fructose, 14, 45, 46, 53
Fruit sugar, 14, 45, 46, 53
Fuel value of feeds, *see* Energy

Gain in farm animals, composition of, 30–3
Galactose, 45, 46, 53
Gallbladder, 38, 45
Gasoline engines compared with farm animals, 102
Gastric juice, 41
Gastric lipase, 42, 54
Gelatine, 45, 51
Gliadin, 87
Glucose, 13, 14
absorption of, 48, 49, 53, 88
composition of, 19
formed in digestion, 45, 46, 53
in animal body, 30, 88
manufacture of, 188–90
Gluten feed, 190
composition of, 190
for breeding stock, 191
fattening stock, 191
growing stock, 190–1
milk cows, 191
work horses, 191
net energy value of, 190
Gluten meal, 190
Glycerin, *absorption of, in intestine,* 49, 54–5
in fats, 19
set free in digestion of fats, 42, 45, 54–5
in saponification of fats, 20
Glycogen, 13
carbohydrates a source of, 87, 88
crude protein a source of, 81
stored in animal body, 30, 88
Grade of animal, influence of, on efficiency of rations, 312–3
Grain, salvage, 229
Grains, 157–87
brewers', 200–1
distillers', 192–3
gross energy value of, 95
influence of grinding and soaking, on digestibility, 69–70
efficiency of ration, 309–10
yeast or vinegar-dried, 231
Grape sugar, *see* Glucose
Grasses, 277–86
Grass hays, 246–55
crude fiber in, 17–8
crude protein in, 12–3
fat in, 21–2
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5

Grass pastures, 277–86
  crude fiber in, 18
  crude protein in, 12–3
  fat in, 21–2
  mineral matter in, 8
  nitrogen-free extract in, 15–6
  water in, 5
Grinding feed, influence of, on digestibility, 69–70
  efficiency of ration, 309–10
Gross energy, 93–5
Ground rock phosphate for pigs, 79
Growth, of animals, composition of increase during, 30–3
    mineral requirements for, 78–80
    protein requirements for, 80–7
    requirements for, 130–4
  of plants, influence of stage of, on digestibility, 71–2
Gullet, 34, 41

Haecker feeding standard for dairy cows, 140–2, 148
  growing fattening cattle, 131–2
Hairy vetch, 245–6, 277
Hansson feeding standard for dairy cows, 151–2
Hay, measurement of, 115–7
Hay bales, estimating weights of, 115–7
Hays, 232–55
  crude fiber in, 12–3
  crude protein in, 12–3
  digestion by different species of animals, 67
  fat in, 21–2
  grass, 246–55
  gross energy of, 95
  leguminous, 232–46
  losses in curing, 72
  mineral matter in, 8
  nitrogen-free extract in, 15–6
  water in, 5
Hay stacks, estimating cubic contents of, 115–7
Heat, a form of energy, 92
  controlling loss of, from body, 104–5
  equalization of, in body, 103–5
  escape of, from body, 103–4
Heat, how produced in body, 103–5
  losses from body, 99–100, 102, 103–4
  lost in digestion, 99–100, 102
  measurement of, 93
  of body, increased by work, 102
  of combustion, 93–5
  production of, in body, 103–5
Heating water for farm animals, 104
Henry-Morrison feeding standards, 124, Appendix Table 33
Herd's grass, *see* Timothy
Hogs
  (For the value of a particular feed for hogs, *see* name of feed)
  composition of bodies of, 26
  concentrates for, 111–2
  cooking feed for, 310
  Dietrich's feeding standard for fattening, 137
  digestible nutrients in feeding stuffs for, Appendix Table 30
  digestion experiments with, 58
  digestion harness for, 57
  digestion of roughages by, 67, 312
  fat in bodies of, 26, 28
  fertilizing elements in manure of, 325
  grinding grain for, 309–10
  influence of patent stock foods on digestibility of rations for, 71
    preparation of feeds on efficiency of rations for, 309–10
  large intestines of, 37
    digestion in, 46–7
  maintenance requirements of, 130
  manure excreted by, per year, 321
  mastication by, 41
  mineral matter in bodies of, 26, 28
  products of, per 100 lbs. digestible organic matter, 311
  protein in bodies of, 26, 30
  relation of weights of, to efficiency of gains, 314
  requirements for fattening, 137
  roughages for, 111–2
  self-feeders for, 153–5
  shelter for, 105

Hogs — *Continued*
small intestines of, 36
stomach of, 34–5
total dry substance and digestible nutrients in feedingstuffs for, Appendix Table 30
water in bodies of, 26, 27
See also Pigs
Hominy chop, 193
Hominy feed, 193
Hominy meal, 193
Honeycomb, *see* Reticulum
Horses
(For the value of a particular feed for horses, *see* name of feed)
ash of feed excreted in manure by, 323
cæcum of, 36–7
calculating rations for, 109–10, 121–3
chaffing hay for, 310
concentrates for, 109–10
digestible nutrients in feedingstuffs for, Appendix Table 29
digestion of roughages by, 67, 138–9
digestive tract of, 39
fertilizing elements in manure of, 325
grade of, as affecting efficiency of rations, 313
grinding grains for, 69–70, 309, 310
Kellner feeding standard for working, 138
large intestines of, 36–7
digestion in, 46–7
liver of, 38
maintenance requirements of, 130
manure, amount excreted per year by, 321
ash of feed excreted in, 323
fertilizing elements in, 325
influence of exposure and fermentation on, 326
nitrogen of feed excreted in, 323
mastication by, 41
nitrogen of feed excreted in manure by, 323
net energy of feed recovered in work by, 305
Horses — *Continued*
rations for, calculating, 109–10, 121–3
requirements of, for growth, 134
maintenance, 130
work, 138–9
roughages for, 109–10
digestion of, 67, 138–9
saliva secreted by, 40
Savage feeding standard fo. growth, 134
self-feeders for, 156
shelter for, 105, 319
small intestines of, 36
stomach of, 34–5
total dry substance and digestible nutrients in feedingstuffs for, Appendix Table 29
type of, as affecting efficiency of rations, 313
work of, as affecting digestibility of rations, 68
net energy value of feeds recovered in, 305
requirements for, 137–9
Hungarian grass, *see* Millet
Hydrochloric acid in gastric juice, 41–2
Hydrogen sulphide formed in large intestine, 47, 52

Increase in body weight of farm animals, composition of, 30–3
Indian corn, *see* Corn
Individuality of animals, influence of, on digestibility, 68
Indol, 47, 52
Inorganic compounds, 2–3
Inorganic phosphate, *see* Calcium phosphate
Intestinal juice, 44, 46
Intestine, large, 36–7
digestion in, 46–7
Intestine, small, 36
digestion in, 44–6
Invertin, *see* Sucrase
Iron in feedingstuffs, 7
Italian rye grass, 253–4
Italian rye grass hay, 253–4

Japan clover, *see* Lespedeza
Jerusalem artichokes, 299–300
Johnson grass, 253
Johnson grass hay, 253
Johnson grass pasture, 282
June grass, *see* Bluegrass

Kafir corn, 182, 258–60
Kafir corn fodder, 258–60
Kafir corn silage, 294–5
Kafir corn stover, 262
Kale, 303–4
Kellner feeding standard for work horses, 138
Kentucky bluegrass, 278–80
Kinetic energy, 93–4
Kohlrabi, 303
Kowliang, 182
Kowliang fodder, 260
Kowliang stover, 262

Labor, *see* Work
Lactase, 44
  action of, on lactose, 45, 46, 53
Lactose, 13, 14
  action of lactase on, 45, 46, 53
  in milk, 52
Lambs
  (For the value of a particular feed for lambs, *see* name of feed)
  Bull-Emmett standard for fattening, 136
    growing, 132–3
  calculating rations for, 112
  composition of bodies of, 26
  concentrates for, 112
  fat in bodies of, 26, 28
  grinding grains for, 70, 310
  mineral matter in bodies of, 26
  protein in bodies of, 26, 30
    requirements for fattening, 136
      growth, 132–3
  rations for, calculating, 112
  roughages for, 112
  water in bodies of, 26, 27
  See also Sheep
Lanolin, 20
Large intestine, 36–7
  digestion in, 46–7

Leaching, influence of, on value of manure, 326–7
Legumes, 270–7
Leguminous hays, 232–46
  crude fiber in, 17–8
  crude protein in, 12–3
  fat in, 22
  mineral matter in, 8
  nitrogen-free extract in, 16
  water in, 5
Leguminous pastures, 270–7
Leguminous seeds, 183–6
  crude fiber in, 17–8
  crude protein in, 12–3
  fat in, 22
  mineral matter in, 8
  nitrogen-free extract in, 15–6
  water in, 5
Length of fattening period, influence of, on efficiency of rations, 317–8
Lespedeza hay, 243–4
    pasture, 274
Lime, *see* Calcium
Lime phosphate, *see* Calcium phosphate
Linseed cake, *see* Linseed oil meal or cake
Linseed meal, *see* Linseed oil meal or cake
Linseed oil, 20
Linseed oil meal or cake, 206–9
  composition of, 207
  for breeding stock, 208–9
    fattening stock, 208
    growing stock, 208
    milch cows, 209
    work horses, 209
  net energy value of, 207
  new process, 207
  old process, 206
Lipase, gastric, 42, 54
  pancreatic, 44, 45, 46, 54
Liquid manure, influence of loss of, on value of manure, 325–6
Liver, 37, 38, 45
  glycogen stored in, 30

Magnesium, in animal body, 28
  feedingstuffs, 7

Maintenance ration, 129
Maintenance requirements of farm animals, 129–30
Maize, *see* Corn
Maltase, 41
  action of, on maltose, 41, 45, 46, 53
Maltose, 14
  action of maltase on, 41, 45, 46, 53
  formed by action of saliva on starch, 40
Malt sprouts, 202
Malt sugar, *see* Maltose
Mammoth clover, *see* Clover, mammoth
Mangels, 297–8
Mangelwurzels, 297–8
Manure, amounts voided by farm animals per year, 321
  ash of feed excreted in, by farm animals, 322–3
  barnyard, benefits soil, 320–1
  care of, to prevent loss, 327
  factors affecting value of, 324–7
  fertilizing elements in, 325
  influence of age of animal on value of, 324
    feeds of ration on, 324
    fermentation on, 326
    leaching on, 326
    species of animal on, 324–5
  losses, 325–6
  nitrogen of feed excreted in, by farm animals, 322–3
Manurial value of feedingstuffs, 327–9
Manyplies, *see Omasum*
Marbling of meat, 31, 32
Mare, *see* Horses
Mastication, 40, 41
  energy lost in, 99
Meadow fescue pasture, 286
Measurement of grain, 113
Meat, marbling of, 31, 32
Meat meal, 216–8
Meat scraps, 219
Metabolism, 76–7
Metabolizable energy, 95–8
  uses in animal body, 97–8
Methane, 43, 54, 95
Middlings, *see* kind of middlings as *Oat middlings*, Wheat middlings, etc.
Milch cows, *see* Cows, dairy
Milk, action of rennin on, 42
  amount produced per 100 lbs. of digestible organic matter, 311
  composition of, 139
  crude protein in, 13
  fat in, 22
  mineral matter in, 8
  nitrogen-free extract in, 16
  skim, 229
  water in, 5
Milk cows, *see* Cows, dairy
Milk production, 139–49
  Eckles feeding standard for, 147–8
  Haecker feeding standard for, 140–2, 148
  Henry-Morrison feeding standard for, Appendix Table 33
  Savage feeding standard for, 142–5, 148
  Wolff-Lehmann feeding standard for, Appendix Table 32
  Woll-Humphrey feeding standard for, 145–6, 148
Milk products, crude protein in, 13
  fat in, 22
  mineral matter in, 8
  nitrogen-free extract in, 16
  water in, 5
Milk sugar, *see* Lactose
Millet, 183
Millet hay, 248–9
Millet pasture, 281
  silage, 281
  straw, 264
Milo maize, 182, 258–60
Milo maize fodder, 258–60
Milo maize silage, 294–5
Milo maize stover, 262
Mineral matter or ash, absorption of, 49, 51
  digestibility of, 63–4
  excretion of, from animal body, 77–8
  functions of, in animal body, 77–80

Mineral matter or ash, in animal and vegetable substances, 6–7
bodies of farm animals, 26, 27–8
feedingstuffs, 7–9
how determined, 8
increase in body weight of steers, 33
manure of farm animals, 325
influence on farm animals of rations deficient in, 78–80
of feed excreted in manure by farm animals, 322–3
required for fertilizing soil, 320
growth, 78–80
Mixed feeds, commercial, 223–6
Molasses, 227
Molasses feeds, 228
Mouth, 34
digestion in, 40–1
Muscles, energy used in work of, 101–2

Net energy, *see* Energy, net
Nitrogen as a fertilizer, 320
in manure of farm animals, 325
of feeds excreted in manure by farm animals, 322–3
Nitrogen-free extract, absorption of, 53
composition of, 14–5
digestibility of, 64–5
digestion of, 52–3
in feedingstuffs, 15–6, 52
how determined, 15
Non-proteins, 11
Nutrients, 2–3
absorption of, 47–50
definition of, 2
digestible, 74–5
in feedingstuffs, Appendix Tables 29, 30, 31, 35
yield of, per acre by various crops, 159
digestion of, 40–7, 50–5
functions of, in animal body, 76–89
gross energy values of, 95
net energy values of, 101
nitrogenous, influence on digestibility of adding to ration, 74
Nutrients, non-nitrogenous, influence of excess of, in ration on digestibility, 73
required by farm animals for fattening, 135–7
growth, 130–4
maintenance, 129–30
milk production, 139–49
wool production, 149
work, 137–9
Nutritive ratio, 89–92

Oat by-products, 202–3
Oat clippings, 203
Oat dust, 203
Oat grass, tall, 253
Oat grass hay, 253
Oat hay, 254
Oat hulls, 202–3
Oat middlings, 202
Oat pasture, 283
Oat shorts, 202
Oat straw, 264
Oats, 169–74
composition of, 171
for breeding stock, 172–3
fattening stock, 172
growing stock, 171–2
milk cows, 173
work horses, 174–5
net energy value of, 171
Oil, definition of, 19
Oil-bearing seeds, 186–7
crude fiber in, 17–8
crude protein in, 12–3
fat in, 21–3
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5–6
Oil by-products, 206–15
crude fiber in, 18
crude protein in, 12–3
fat in, 21–2
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5–6
Oil cake, *see* Linseed meal or cake
Oils, 20
Olein, 19

Omasum, 35–6
digestion in, 42–3
Orchard grass, 250
Orchard grass hay, 250
Orchard grass pasture, 282
Organic acids, 14
Organic compounds, 2–3
Organic matter, products yielded by various farm animals from 100 lbs. of digestible, 311
Oxygen, 18, 19

Packinghouse by-products, 216–20
crude fiber in, 18
crude protein in, 12–3
fat in, 21–2
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5–6
Palatability, influence of, on digestibility of rations, 68–9
Palmitin, 19
Pancreas, 37, 38
Pancreatic amylase, 44, 45, 53
Pancreatic juice, 38, 44, 45
Pancreatic lipase, 44, 45, 46
Pasture, 266–7, 270–86
classes of, 266–7
crude fiber in, 18
crude protein in, 12–3
definition, 266
fat in, 21–2
grasses, 277–86
legumes, 270–7
mineral matter in, 8
nitrogen-free extract in, 15
water in, 5
Patent stock foods, influence of, on digestibility, 70–1, 221–2
Paunch, *see* Rumen
Pea, Canada field, 183–4
for hay, 244
Peanut hay, 244
Peanut hulls, 215
Peanut meal or cake, 214
Peanut pasture, 274
Peanuts, 185–6
Peat, 300
Pentosans, 13, 43
Pepsin, 42, 51
Peptids, 45, 51
Peptones, 42, 45, 46, 51, 52
Perennial rye grass pasture, 286
Perspiration, loss of body heat by, 103–4
Phosphatides, 20–1
Phosphorus, as a fertilizer, 320
excretion of, from animal body, 78
in animal body, 28
feedingstuffs, 7
influence on pigs, of rations deficient in, 79–80
in manure of farm animals, 322, 325
inorganic, for pigs, 79
of feeds, excreted in manure by farm animals, 322–3
Pigs
(For the value of a particular feed for pigs, see name of feed)
addition of nitrogenous nutrients to rations of, as affecting digestibility, 73
ash of feed excreted in manure by, 322–3
calcium-poor rations, effect on, 79–80
composition of bodies of, 26
concentrates for, 111, 112
Dietrich's feeding standard for growing, 133
efficiency of gains as affected by previous fasting, 317
as related to body weight, 314
excess of non-nitrogenous nutrients in rations as affecting digestibility, 73
fat in bodies of, 26
feeding rock phosphate to, 79
grinding grains for, 70
individuality of, as affecting digestibility of rations, 68
influence of rations deficient in mineral matter on, 78–80
in protein on, 83–7
mineral matter in bodies of, 26
required for growth, 78–80, 131

Pigs, nitrogen of feed excreted in manure by, 323
phosphorus-poor rations, effect on, 79–80
protein in bodies of, 26
rations for, calculating, 111, 112
relation of body weight to efficiency of gains, 314
roughages for, *111*, *112*
strength of bones as affected by feed, 79–80
water in bodies of, 26, 27
weights of, as related to efficiency of gains, 314
See also Hogs
Plants, carbohydrates in, 13
crude fiber in, 16–7
fat in, 18
mineral matter in, 6–7
nitrogen-free extract in, 14–5
non-proteins in, 11
protein in, 9
stage of growth of, as affecting digestibility, 71–2
storage of energy by, 92
water in, 4
Potassium, as a fertilizer, 320
in animal body, 28
feedingstuffs, 7
manure of farm animals, 322–3, 325
of feeds excreted in manure by farm animals, 322–3
Potatoes, 299
Potato starch, 13
Potential energy, 92–3
Poultry, products of, from 100 lbs. digestible organic matter, 311
Prairie hay, 253
Pregnant animals, feed requirements of, 134
Preparation of feeds as affecting digestibility of rations, 69–70
efficiency of rations, 309–10
Previous treatment of animals as affecting efficiency of rations, 316–7
Products of various farm animals from 100 lbs. digestible organic matter, 311
Proprietary feeds, influence of, on digestibility of rations, 70–1, 221–2
Protein, 9
absorption of, 48, 51–2
composition of, 10
crude, 9
body fat formed from, 81–2
digestibility of, 64
energy derived from, 80–1
functions of, in animal body, 80–2
in feedingstuffs, 12–3
glycogen derived from, 81–2
digestion of, 42, 44–5, 46, 47, 51–2
gross energy value of, 95
in bodies of farm animals, 26, 29–30
influence on pigs, of rations deficient in, 83–7
in increase in body weight of farm animals, 31–3
net energy values of, *101*
nutritive value of, 9, 10–11, 80–2
required for growth, 9, 80, 81, 82
Proteoses, 42, 45, 46, 47, 51, 52
Ptomaines, 47, 52
Ptyalin, 39–41, 52–3
Pumpkins, 304

Quantity of feed, how determined for rations, 112–3
influence of, on digestibility of rations, 72–3
efficiency of rations, 307–9

Radiation, loss of body heat by, 103–4
Rape, 301–2
Rape seed cake, 215
Ratio, nutritive, 89–92
Rations, amounts of, as affecting digestibility, 72–3
efficiency, 307–9
balanced, 119
composition of, as affecting efficiency, 306–7

Rations, compounding of, according to feeding standards, 121–3, 125–9, 139–49
for beef cattle, 111
dairy cows, 110–11, 139–49
fattening, 135–7
growth, 130–4
hogs, 111–2
horses, 109–10
maintenance, 129–30
milk production, 139–49
pregnancy, 134
sheep, 112, 149
wool production, 149
work, 137–9
general rules for, 107–13
deficient in mineral matter, influence of, on pigs, 78–80
protein, influence of, on pigs, 83–7
digestibility of, as affecting efficiency, 307
factors affecting, 66–74
efficiency of, 305–19
factors affecting, 306–19
excess of non-nitrogenous nutrients in, as affecting digestibility, 73–4
feed-unit system of calculating, 149–52
maintenance, 129–30
palatability of, as affecting digestibility, 68–9
preparation of, as affecting digestibility, 69–70
efficiency, 309–10
standards for, *see* Feeding standards
vitamines in, 22–4
Raw bone meal, 219–20
Red clover, *see* Clover, red
Red dog flour, 198–9
Red top grass hay, 250
Red top grass pasture, 282
Red top straw, 264
Refuse, cannery, for silage, 295
Rennin, 42
Respiration calorimeter, 96–7
Reticulum, 35, 36
digestion in, 42–3
Rice, 183
Rice bran, 204
Rice by-products, 204
Rice hulls, 204
Rice polish, 204
Rock phosphate for pigs, 79
Roots, 296–300
crude fiber in, 18
crude protein in, 12–3
fat in, 21–2
mineral matter in, 8–9
nitrogen-free extract in, 15–6
water in, 5
Roughages, compared with concentrates in digestibility of:
crude fiber, 65–6
crude protein, 64
fat, 66
nitrogen-free extract, 64–5
definition, 106
estimating weights of, 115–7
in rations, 112–3
net energy value of, 106
proportion of, to concentrates as affecting efficiency of gains, 307
subclasses, 157–8
valuation of, as compared with concentrates, 114
Rumen, 35, 36
digestion in, 42–3
Ruminants, mastication of, 41
stomachs of, 35–6
digestion in, 42–4
Rumination, 41
energy used in, 99
Rutabagas, 299
Rye, 174–5
composition of, 174
distillers' grains from, 204
for breeding stock, 175
fattening stock, 175
growing stock, 174–5
milk cows, 175
work horses, 175
net energy value of, 174
Rye bran, 203
Rye by-products, 203–4
Rye feed, 204

Rye grass hay, Italian, 253–4
Rye grass pasture, Italian, 283
perennial, 286
Rye hay, 254–5
Rye middlings, 203–4
Rye pasture, 283
Rye shorts, 203
Rye straw, 264

Saliva, action on food, 40–41
amount secreted, 40
Salivary amylase, 39–41, 52–3
Salivary glands, 37–8, 40
Salt, common, influence of, on digestibility, 71
required by farm animals, 78
Salvage grain, 229
Saponification, 20
Savage feeding standard for dairy cows, 142–5, 148
Seeds, 157–87
crude fiber in, 17–8
crude protein in, 12–3
fat in, 22
leguminous, 183–6
mineral matter in, 8
nitrogen-free extract in, 15–6
oil-bearing, 186–7
water in, 5–6
Self-feeders, 152–6
for cattle, 155–6
hogs, 153–5
horses, 156
sheep, 156
Sesame seed cake, 215
Shallu, 182, 260
Shallu fodder, 260
Shallu stover, 262
Sheep
(For the value of a particular feed for sheep, *see* name of feed)
amount of feed as affecting digestibility of rations for, 73
ash of feed excreted in manure by, 323
composition of bodies of, 26
concentrates for, 112
digestible nutrients in feedingstuffs for, Appendix Table 29
Sheep, fat in bodies of, 26, 28
fertilizing elements in manure of, 325
grinding grains for, 70, 310
large intestines of, 37
maintenance requirements of, 130
manure, amount excreted per year by, 321
ash of feed excreted in, 323
fertilizing elements in, 325
nitrogen of feed excreted in, 323
mineral matter in bodies of, 26, 28
nitrogen of feed excreted in manure of, 323
products of, per 100 lbs. digestible organic matter, 311
protein in bodies of, 26, 30
requirements for fattening, 136
wool production, 149
roughages for, 112
utilization of, compared with other animals, 67, 312
self-feeders for, 156
small intestines of, 36
species of, as affecting efficiency of rations, 310
stomachs of, 35–6
total dry substance and digestible nutrients in feedingstuffs for, Appendix Table 29
type of, as affecting efficiency of rations, 313
water in bodies of, 26, 27
wool production, requirements for, 149
See also Lambs
Shelter for farm animals, 104–5, 319
Shipstuff, 199
Shoats, concentrates and roughages for, 112
See also Hogs, Pigs
Shorts, *see* kind of shorts, as Oat shorts, Rye shorts, etc.
Silage, 287–95
advantages of, 288–9
alfalfa for, 294
beet pulp for, 295
cannery refuse for, 295
clover for, 294

Silage, corn for, 289–94
composition of, 290
for beef cattle, 292–3
dairy cows, 291–2
hogs, 294
horses, 293–4
sheep, 293
influence of fermentation on, 290–1
net energy value of, 290
yield per acre, 290
cowpeas for, 294
crude fiber in, 18
crude protein in, 12–3
fat in, 22
feterita for, 294–5
kafir corn for, 294–5
milo maize for, 294–5
mineral matter in, 8
nitrogen-free extract in, 15–6
soft corn for, 290
sorghum bagasse for, 295
soybeans for, 294
sweet sorghum for, 294–5
water in, 5
Silo, 287–9
capacity of, 118
requisites of a good, 287–8
Skatol, 47, 52
Skim milk, 82, 229
Skin, loss of heat from, by evaporation from, 103–4
conduction and radiation from, 103–4
Slaughter-house by-products, 216–20
Slender wheat grass, 254
Slender wheat grass hay, 254
Small intestine, 36
digestion in, 44–6
Soaking feed, influence of, on digestibility of feedingstuffs, 69
efficiency of rations, 310
Soap, how made, 20
Sodium, in animal body, 28
feedingstuffs, 8
Soft corn, 166
for silage, 290
Soilage, 267–86
advantages of, 268–9
Soilage, crops for, 267–86
definition, 267
disadvantages of, 268–9
grasses for, 277–86
legumes for, 270–7
Sorgho, *see* Sorghum, sweet
Sorghum, sweet, 179–82
Sorghum bagasse silage, 295
Sorghum fodder, sweet, 258
Sorghum hay, 249
Sorghum pasture, 281–2
Sorghum silage, sweet, 294–5
Sorghum stover, 262
Sorghums, grain, 179–82
sweet, 179–82
Sows, *see* Hogs and Pigs
Soybean, 185
Soybean cake, 214
Soybean hay, 245
Soybean meal, 214
Soybean pasture, 277
Soybean silage, 294
Soybean straw, 264
Species of animal, influence of, on digestibility, 66–7
efficiency of rations, 310–2
value of manure, 324–5
Spelt, 179
Sperm oil, 20
Stacks, hay, estimating cubic contents of, 115–7
Stage of growth of plant, influence of, on digestibility, 71–2
Stallion, *see* Horses
Standards of feeding, *see* Feeding standards
Starch, 13, 14
action of pancreatic amylase on, 45
ptyalin on, 40, 52–3
manufactured from corn, 188–9
Steam engine and animal compared, 96, 100
Steapsin, *see* Pancreatic lipase
Stearin, 19
Steers, addition of nitrogenous nutrients to ration as affecting digestibility, 74
age of, as affecting digestibility of rations, 67
efficiency of rations, 314–5

Steers, amount of feed, influence of, on digestibility of rations, 72–3
efficiency of rations for, 307–8
ash in bodies of, 26, 29
of feed excreted in manure of, 323
breed of, as affecting digestibility of rations, 67
calculating rations for, 111, 125–6
capacity of, as affecting efficiency of rations, 315–6
composition of bodies of, 26
increase in body weight of, 32–3
concentrates for, 111
condition of, as affecting digestibility of rations, 67
fat in bodies of, 26, 28, 29
fertilizing elements in manure of, 321–2
grade of, as affecting efficiency of rations for, 312–3
Haecker's feeding standard for fattening, 131–2
increase in body weight of, composition, 32–3
length of fattening period, influence of, on efficiency of gains, 317–8
manure, ash of feed excreted in, 323
fertilizing elements in, 321–2
loss in, from exposure to weather, 326
nitrogen of feed excreted in, 323
mineral matter in bodies of, 26, 29
net energy required by, for 1 lb. of gain, 314
nitrogen of feed excreted in manure by, 323
patent stock foods, influence of, on digestibility of rations, 71
preparation of feeds as affecting efficiency of rations, 311–2
previous treatment as affecting efficiency of rations, 316, 317
products of, from 100 lbs. of digestible organic matter, 311–2
Steers, protein in bodies of, 26, 29
requirements for fattening, 131–2, 136
roughages for, 111
self-feeders for, 155–6
shelling corn for, 309
temperament of, as affecting efficiency of rations, 316
water in bodies of, 26, 29
Stimulant, prescription for, 222–3
Stock foods, patent, influence of, on digestibility, 70–1, 221–2
Stomach, 34–5
digestion in, 41–4
of cow, 35
hog, 34–5
horse, 34–5
ruminants, 35–6
digestion in, 42–4
sheep, 35
simple, 34–5
digestion in, 41–2
Storage of carbohydrates as glycogen and fat in animal body, 87, 88
crude protein as glycogen and fat in animal body, 81–2
energy in animal body, 105
fat in animal body, 81–2, 87, 88, 89
feedingstuffs, influence of, on digestibility, 72
glycogen in animal body, 81–2, 87, 88
Stovers, 256–62
crude fiber in, 17–8
crude protein in, 12–3
fat in, 22
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5
Straws, 263–5
crude fiber in, 17–8
crude protein in, 12–3
fat in, 21–2
mineral matter in, 8
nitrogen-free extract in, 15–6
water in, 5
Sucrase, 44, 46
action of, on sucrose, 46, 53
Sucrose, 13, 14, 52
action of sucrase on, 46, 53

Sudan grass, 249–50
Sudan grass hay, 250
Sugar-beet pulp, *see* Beet pulp
Sugar beets, 298
Sugars, 13, 14
absorption of, 48, 53
Sulphur, in animal body, 28
feedingstuffs, 7
Sunflower-seed cake, 215
Sweating of feeds, influence of, on digestibility, 69
Swedes, 299
Swedish clover, *see* Clover, alsike
Sweet clover, *see* Clover, sweet
Sweet sorghum, *see* Sorghum, sweet
Swine, *see* Hogs and Pigs

Tall oat grass, 253
Tall oat grass hay, 253
Tankage, 216–8
Teeth, 37
Temperament of animal, influence of, on efficiency of rations, 316
Temperature, influence of, on efficiency of rations, 319
Therm, 93
Timothy grass, 280–1
Timothy hay, 246–8
Timothy pasture, 280–1
Timothy straw, 264
Tin-plate by-product, 230
Tongue, 37
Tonic, prescription for, 222–3
Treatment of animal, influence of, on efficiency of rations, 316–7
Trypsin, 44–5, 51, 52
Turnips, 299
Type of animal, influence of, on efficiency of rations, 312–3

Urine, amounts voided by farm animals per year, 321
fertilizing elements in, 322, 325
influence of loss of, on value of manure, 325
mineral matter of feeds excreted in, by dairy cows, 322
Utilization of energy, coefficient of, 102–3

Valuation of feedingstuffs, 330–3
Van Norman feeding standard for dairy cows, 128–9
Vegetable meal, 230–1
Velvet bean hay, 244
Velvet bean pasture, 274
Vetch, common and hairy, for hay, 245–6
for pasture, 277
Villi, 47–9
Vinegar-dried grains, 231
Vital processes, energy consumed in, 98–9
Vitamines, 22–4
Voluntary muscles, energy consumed in work of, 101–2

Water, absorption of, 49, 50
composition of, 3
function of, in plants, 4
in animal body, 77
how excreted from animal body, 77
in bodies of farm animals, 26–7
function, 77
feedingstuffs, 4–6
how determined, 5
nutritive value, 9
warming for farm animals, 104
Watering farm animals, influence of frequency on digestibility, 70
Waxes, 20
Weight, body, composition of increase in, 30–3
Western wheat grass, 254
Western wheat grass hay, 254
Wet beet pulp, 228
Wet brewers' grains, 199–201
Wethers, *see* Sheep
Wetting feeds, influence of, on digestibility, 69
efficiency of rations, 310
Wheat, 166–9
composition of, 167
for breeding stock, 169
fattening stock, 168–9
growing stock, 167–8
milk cows, 169
work horses, 169
kinds of, 167
net energy value of, 167

Wheat, spring, 167
winter, 167
Wheat bran, 194–6
composition of, 194
for breeding stock, 196
fattening stock, 195–6
growing stock, 195
milch cows, 196
work horses, 196
net energy value of, 194
Wheat by-products, 193–200
Wheat grass, 254
Wheat grass hay, 254
Wheat middlings, 197–8
Wheat pasture, 284
Wheat screenings, 200
Wheat shorts, 197
Wheat starch, 13
Wheat straw, 264
Whey, 230
White clover, *see* Clover, white
Wolff-Lehmann feeding standards, 120–1, Appendix Table 32
Woll-Humphrey feeding standards for dairy cows, 145–6, 148
Wool fat, 20
Wool production, requirements for, 149
Work, influence of, on digestibility, 67–8
of digestion and absorption, energy consumed in, 99–100
vital processes, energy consumed in, 98–9
voluntary muscles, energy consumed in, 101–3
heat produced in, 102
influence of, on digestibility, 67–8
requirements by horses for, 138–9
sources of energy for, 80, 87, 88, 89
requirements of farm animals for, 137–9
Work horses, *see* Horses

Yeast-dried grains, 231

Zein, 83

Printed in the United States of America.

THE following pages contain advertisements of a few of the Macmillan books on kindred subjects